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Metropolitan District Commission

Water Supply Study and
Environmental Impact Statement–2020

Task 3:
Demand Management

Summary Report

GOVERNMENT DOCUMENTS
COLLECTION

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GLOSSARY

Accounted-for Water - the amount of water recorded on all consumer meters in a community, plus estimates of consumption for consumers with no meters or stopped meters.

Baseline Water Conservation Activities - those actions taken by water users or communities to reduce use independent of a MDC-sponsored demand management plan.

Cooling Use - water used by nondomestic users which reduces the temperature of a manufactured product, the manufacturing equipment, or the space. Contact cooling water is water which comes in direct contact with the product; noncontact cooling water does not.

Current Dollars - the value of money spent at some future date, adjusted to reflect the effects of inflation.

Demand Simulation Model - a computer model for estimating future water demand based on projections within individual water use sectors (domestic, nondomestic, and unaccounted-for water) and different types of water use (sanitary, process, cooling, outdoor, and other).

Domestic Water Use - metered residential use of water, excluding nursing homes, colleges, hospitals, prisons, and other institutions.

Drought Response Plan - series of short-term emergency actions, including demand reduction and supply augmentation, that would be implemented only during drought periods.

Economic Analysis - the derivation of the present value of a demand management (or supply augmentation) program which would be implemented by the MDC during the 40-year planning period, which does not include costs of program financing.

Financial Analysis - the derivation of the present value of a demand management (or supply augmentation) program implemented during the 40-year planning period, including costs of program financing, if relevant.

in situ - occurring in a natural place.

Long-term Programs - a demand management program which would be implemented to reduce average water use throughout the 40-year planning period.

MG - million gallons.

MGY - million gallons per year.

MGD - million gallons per day.

Major Water Users - industries, utilities, and large institutions which use more than 10 million gallons of water per year.

Metered Use - the amount of water used measured by consumer meters.

Metered Use Ratio - the ratio of accounted-for water to total water produced or purchased by a community, expressed as a decimal.

NPV - net present value, see definition for net present value.

NPV/MG - net present value per million gallons.

Net Present Value - total present value of a project (total capital, operation and maintenance costs) minus the residual value of any structure(s) associated with the project.

Nondomestic Water Use - all metered nonresidential use of water, including institutions, industries, power plants, stores, offices, restaurants, etc.

Non-Potable Water - a term, used for this report, to differentiate between water supplied by the public or potable water supply system, and water that could be supplied from a source other than the potable water supply system. Non-potable water would be used for purposes which do not need potable water quality. Types of non-potable water include treated wastewater effluent, seawater, groundwater, and surface water.

Other Unaccounted-for Water - the difference between total unaccounted-for water and those components of unaccounted-for water which can be estimated (meter under-registration, public unmetered use, and recoverable leakage). Examples of uses in this category are unavoidable leakage, and evaporation from reservoirs.

psi - pounds per square inch, a unit for measurement of pressure.

Planning Area Communities - the 36 potential future user communities plus the existing 44 MDC user communities. At the time of report preparation, the City of Lynn was not part of the MDC. For this analysis, it is part of the potential future users.

Potential Future Users - 36 communities not currently part of the MDC, which during an initial screening process, were identified as having a possible future water deficit, and which could become MDC users.

Present Value - the calculation of the current value of money spent at a future date, which has been adjusted to reflect the effects of inflation, and discounted to reflect the value of money at the current time.

Process Use - water used by industries that is part of the manufactured product, or is used in the production of the product.

Proposition 2½ - a state referendum passed by Massachusetts voters in 1979 to limit taxation within the Commonwealth, which specified that direct use charges for services such as water supply not exceed cost of service. (Note: cost of service limitation has recently been amended.)

Quabbin Minimum Pool - the level of Quabbin Reservoir that represents the lowest level to which the reservoir could be drawn, and still meet water quality and ecological requirements.

Recoverable Leakage - the amount of leakage which can be detected and is economical to repair.

Residual Unaccounted-for Water - the difference between total unaccounted-for water and meter underregistration and public unmetered water.

Response Rate - a number derived to represent the percentage of households, businesses, or communities which would implement a particular demand management program.

Retrofit Devices - devices that are installed in existing standard plumbing fixtures to reduce the amount of water used.

Revenue Meters - MDC meters which measure the quantity of water delivered to each community.

Safe Yield Model - a computer model which simulates the MDC reservoir system storage capacity, based on a 50-year historical precipitation record, established system operating rules, and a specified withdrawal rate.

Short-term Programs - a demand management program implemented specifically to reduce use during a drought emergency period which would be suspended after the drought emergency.

Unaccounted-for Water - the difference between the total amount of water produced or purchased by a community and accounted-for water.

Unavoidable Leakage - the amount of leakage which is too small to detect and/or to economically repair.

Water Demand - estimates of the total future demand in the MDC for water without estimates of potential water demand reductions which could result from demand management strategies.

Water Needs - estimates of the total future need for water in the MDC system to the year 2020, including estimates of potential water demand reductions which could result from demand management strategies.

Water Saving Devices - plumbing fixtures which use a minimum amount of water.

Water Saving Factor - a number derived to represent the amount of water which could be saved by a household, business, or water system after implementation of a demand management program.

SUMMARY

INTRODUCTION

Demand Management is one of nine alternatives being studied, as part of the MDC Water Supply Study and Environmental Impact Report - 2020 (EIR), to identify a long-term program to meet the MDC's water needs over the next 40 years. Unlike the other supply augmentation alternatives which have one course of action, this alternative included a preliminary review of 11 possible demand management programs, from which one final plan will be selected. The 11 different programs were selected for this detailed analysis during Phase I of the study, and include the following:

- unaccounted-for water and system leakage reduction;
- pressure reduction;
- domestic leak recovery;
- domestic device retrofit;
- nondomestic conservation;
- water pricing;
- tax incentives;
- public building device retrofit;
- nonemergency education;
- use of non-potable water for selected large users; and,
- drought response planning.

The final plan the MDC selects for implementation may include a combination of a number of individual programs. The water savings achievable by implementation of the selected plan will be subtracted from the projected water demand to derive the projected water needs for the MDC. The selected demand management plan will become part of the final plan of the water supply study and will be assessed as one alternative in the EIR.

The first step of the demand management analysis included a detailed assessment of each of the 11 programs. This analysis identified the costs, water savings, and impacts which might be anticipated from the implementation of each program within the 44* current MDC user communities and the 36 potential future user communities. The determination of the planning area is described in the Draft Technical Report: Planning Area (WFA, 1982), and a summary is presented in the section "Derivation of Planning Area" of that report. Water savings were projected for each group of users (current users referred to as "MDC", and potential future users referred to as "nonMDC") for the years 1990, 2000, and 2020.

The second step of the analysis was the combination of programs to be included in four illustrative water conservation plans. The four possible plans are based on different approaches to achieve implementation and include:

- a plan which would not rely on user participation (Strategy No. 1 - Public Agency Action Programs);
- a plan which would rely only on voluntary user participation (Strategy No. 2 - Combined Public Agency and Private Action);
- a plan which would provide users with direct technical assistance (Strategies No. 2 and No. 3 - Combined Public Agency and Private Action, and Potential Use of Non-Potable Water Sources); and,
- a plan which would rely on participation from all use sectors (Strategies No. 1 and No. 2 - Public Agency Action Programs, and Combined Public Agency and Private Action).

These plans demonstrate how the costs and water savings of individual programs may change when implemented simultaneously. For example, when a domestic device retrofit program is implemented simultaneously with a public education program encouraging installation of devices, the same type of water savings achieved by device installation are included in both programs. Therefore water savings for the program combination might only be equivalent to water savings expected from one program.

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*Lynn was not yet a member of the MDC when this study was initiated; it was included in the potential future user communities.

The final plan for implementation will be selected on the basis of the unit cost of the programs (cost per million gallons of water saved), total quantity of water savings, expected reliability of water savings, impacts on the water users, and impacts on system operation, and it may not be one of the four illustrative plans. Another major consideration for plan selection will be its implications to MDC management and includes concerns such as ability to obtain authorization for new staff positions, ability to increase the annual operating budget to fund annual programs continuously over the 40-year planning period, and legal authority to implement portions of some programs.

FINDINGS

The major findings of the demand management task include the following.

- The water conservation actions already implemented by the state, the MDC, and private users will contribute significantly to the reduction of average water use over the planning period within the domestic and nondomestic sectors. The influence of these ongoing actions have been incorporated into the demand projections. As a result, additional water savings from demand management programs decline as baseline actions increase. For example, the domestic indoor bathroom water use is projected to decline from the current 55 gallons per capita per day (gpcd) to only 42 gpcd by 2020 without further MDC action. This decline is due primarily to the Massachusetts plumbing code which requires that water conserving plumbing fixtures be installed in all new construction and renovation projects.

- The MDC could reduce the projected water demand through 2020 with demand management. The water savings would vary substantially, depending on the final programs selected. Savings from individual programs could range from 0.3 MGD by 2020 up to 13.5 MGD.

- The net present value cost to the MDC per million gallons of water saved for individual programs range from $33 per million gallons to over $1000 per million gallons.

- The projected water savings from programs which affect the three use sectors, domestic, nondomestic, and unaccounted-for water, vary significantly over the planning period, due to the effects of baseline water conservation activities.

- The total quantity of water savings and the percentage reduction in demand anticipated from domestic programs decline significantly between 1990 and 2020, primarily due to the plumbing code. Therefore, domestic water conservation programs are most effective during the first 10 years of the planning period, before full compliance with the plumbing code is achieved.

- The quantity of water savings from nondomestic programs increases somewhat not as a result of increase in water savings from water conservation programs, but primarily due to the projected increase in total nondomestic water use. The percentage water savings over total nondomestic demand declines between 1990 and 2020 similar to the domestic water savings.

- The quantity and percentage of water savings from water system leak detection and repair increases as total water demand increases. Savings would be expected to increase as the results of the implementation of Massachusetts Chapters 805 and 286 Water System Rehabilitation grant programs decline. The leakage recovered from this program is likely to recur without further programs after the year 2000.

• Demand management programs implemented on a regional scale are not as effective on a system-wide basis as programs implemented within one community. The major reasons for this effect include the following:

  - difficulty in obtaining consistent implementation of the program among the different local governments;

  - the wide range of water users requires a complex variety of demand management programs; and,

  - the range of water use patterns within water use sectors results in wide ranges in expected water savings.

• Water savings from demand management programs that include installation of hardware and do not rely completely on user participation are more reliable over the long term. The most reliable water savings are achieved from water system leak detection and repair, domestic device retrofit, nondomestic

conservation, and use of non-potable water for selected large users.

- Public education, as an independent program during nonemergency periods, does not appear to be cost-effective because an extremely aggressive program is required to achieve significant water savings.

- The effect of water pricing as an independent program to encourage significant water savings in the MDC region is relatively minor because of the low cost of water. To encourage significant water savings, water prices would have to be more than doubled above full cost recovery rates. Because of the constraints of charging more than cost recovery for public services, water pricing does not appear to be an effective technique.

- Water savings and costs of two, or more, demand management programs can not be simply added together to yield total water savings and costs. The simultaneous implementation of demand management may result in duplicating costs or water savings that would significantly affect the total water savings and costs that can be expected from the individual programs.

ORGANIZATION OF REPORT

The demand management report is presented in two parts: this summary report, and the Demand Management: Interim Technical Report, which is the full report on the individual programs that were studied. The summary includes an overview of the results of the 11 individual program assessments, as well as a detailed review of how the individual programs were combined into four illustrative plans. The water savings and impacts of the four plans are presented, as well as the general methodology used to derive the water savings and costs.

The Demand Management: Interim Technical Report includes complete reports on each of the 11 demand management programs studied. For each program, the following information is included:

- background research, including literature review, interviews, and case studies;

- methodology used to estimate water savings for each program;

- full description of three levels of effort for programs which encourage user participation;

- derivation of water saving factors, response rates, or other coefficients used in the water saving estimation methodology; and,

- the implications to MDC management of the program.

Community-by-community water savings for each program are presented if the accuracy of the data were sufficient; otherwise, water savings are presented as one estimate for current MDC communities and one estimate for potential future user communities.

After this report has been reviewed and comments received from the public, the MDC will select the final demand management plan for implementation. The final demand management plan will be summarized in the Water Needs Report.

Planning Area

The planning area for the demand management task includes two types of communities: 44 existing MDC user communities, including both fully supplied and partially supplied communities; and 36 potential future user communities not now part of the MDC system. Table 1, "Communities in the Planning Area", lists the communities.

The 36 potential future user communities were selected for study during the preliminary screening of over 250 communities. The purpose of the preliminary screening was to identify those communities which might experience a water supply deficit in the future and which might become future users of the MDC system.

Detailed water demand projections were then completed for the 36 communities selected from the preliminary screening to determine if those communities would be expected to experience a shortfall. Shortfalls were defined as the difference between the present safe yield of a community's supply and the detailed projections of demand for that community. If no shortfalls were anticipated, then those communities did not receive further analysis in the study. The detailed demand projections (refer to Water Demand Projections report) indicated that 12 communities out of the original 36 would be potential deficit communities.

Because the demand management analysis began simultaneously with the demand projections work,

Table 1. Communities in the Planning Area

CURRENT USERS OF THE MDC SYSTEM

Community Users

Arlington	Stoneham	Cambridge (P)
Belmont	Swampscott	Canton (P)
Boston	Waltham	Needham (P)
Brookline	Watertown	Peabody (P)
Chelsea	Winchester (P)	Wakefield (P)
Everett	Winthrop	Weston (P)
Lexington	Chicopee *	Wellesley (N) (P)
Malden	Wilbraham *	Woburn (P)
Marblehead	Clinton *	Worcester * (P)
Medford	Melrose	Leominster * (P)
Milton	Framingham * (P)	Northborough * (P)
Nahant	Marlborough * (P)	Lynnfield Water District
Newton	Southborough *	Revere
Norwood	Quincy	South Hadley Fire District No. 1 *
Somerville	Saugus	

Special Users

Fernald School & Metropolitan State Hospital *	Westboro State Hospital *
G.S.A. *	Lynn - General Electric * (see Footnote 1)
MDC Parks Division *	
MDC Sewerage Division *	

POTENTIAL FUTURE USER COMMUNITIES

Acton °	Easton	North Reading +
Amherst	Fitchburg	Paxton
Ashland	Holden	Randolph +
Athol °	Holbrook +	Rutland °
Avon +	Hopkinton	Sterling
Bedford + °	Hudson °	Stoughton + °
Billerica +	Lancaster	Tyngsborough °
Braintree +	Lynn ° (see Footnote 1)	Ware
Brockton °	Lynnfield +	Westwood +
Chelmsford	Middleton + °	Westborough
Danvers + °	Natick +	Whitman °
Dedham +	North Andover	Wilmington + °

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* Non-member of Metropolitan Water District (Contract User)
(P) Partially Supplied
(N) Currently Takes No Supply
\+ Legally-eligible communities are at least in part within fifteen miles of the State House according to the General Laws, Chapter 92, Section 10.
° Projected to face local water supply deficits by 2020.

estimations of water savings were done for all 36 potential future user communities in the event that all 36 would eventually be part of the capacity planning estimate. Because not all 36 communities were included in the capacity planning estimate, the total quantity of water savings projected within this task is not directly related to the total projected demand for the potential future user category of the Water Demand Projections report. However, the percentage of water savings of projected demand for the 36 communities will be applied to the 12 deficit communities to determine final water needs and final volume of water savings for those communities.

When the MDC selects a final demand management plan for implementation, the percentage water use reduction that could be expected from that plan will then be applied to existing users and potential future users in the Water Demand Projections report to yield the final water needs.

OVERVIEW OF INDIVIDUAL PROGRAMS

Eleven major demand management programs for long-term and short-term application were studied to estimate costs and water savings potential. Each program is summarized below with the anticipated water savings and costs for the existing 44 MDC user communities. All costs are reported as unit costs, based on total net present value divided by total water savings achieved over the planning period. The cost methodology is described in more detail in "Derivation of Program Costs" section of this report. Water savings and costs for the 36 potential future user communities, as well as for MDC communities, are presented in Tables 2 and 3 "Water Savings and Costs for Long-term Demand Management Programs", and "Summary of Drought Response Plan".

- Unaccounted-for water and system leakage reduction is a long-term program which includes improving the accuracy of domestic and nondomestic meters, reducing unmetered public water use (fire fighting, street cleaning, and main/sewer cleaning), and reducing leakage from community distribution systems. The average daily water savings expected from this program would be 7.9 MGD, most of which would be achieved between the years 2000 and 2020; the unit costs would be $261/MG.

- Pressure reduction is a long-term program which includes reducing water use and leakage by decreasing water main pressure in high pressure zones. The average daily water savings from this

Table 2. Water Savings and Costs for Long-Term Demand Management Programs

PROGRAM	UNIT COST, Net Present Value per Million Gallons Saved	WATER SAVINGS, in MGD 1990	2000	2020
Improved System Management Practices - Leak Detection and Repair Only				
MDC*	$261/MG	3.4	5.3	13.5
nonMDC**	$293/MG	0.5	1.8	4.5
Pressure Reduction				
Low				
MDC		2.5	2.5	2.5
nonMDC	$92/MG	1.7	1.7	1.7
Moderate				
MDC	$201/MG	4.3	4.3	4.3
High				
MDC	$267/MG	4.8	4.8	4.8
Domestic Leak Recovery				
Low				
MDC	$354/MG	0.8	0.8	0.9
nonMDC	$264/MG	0.2	0.3	0.3
Moderate				
MDC	$188/MG	2.0	2.1	2.2
nonMDC	$195/MG	0.6	0.7	0.8
High				
MDC	$1004/MG	7.1	7.4	8.0
nonMDC	949/MG	2.2	2.4	2.8
Domestic Device Retrofit				
Low				
MDC	$128/MG	3.7	2.8	1.3
nonMDC	93/MG	1.4	0.9	0.3
Moderate				
MDC	$253/MG	7.3	5.9	2.7
nonMDC	$215/MG	3.2	2.2	0.9
High				
MDC	$235/MG	24.1	19.4	9.4
nonMDC	$320/MG	9.0	7.1	3.3

* 44 current MDC user communities
** 36 potential future user communities

Table 2 continued

Nondomestic Conservation				
Low				
MDC	$2/MG	2.6	1.7	1.6
nonMDC	Insignificant	1.8	0.8	0.3
Moderate				
MDC	$33/MG	5.5	6.8	8.0
nonMDC	$35/MG	1.1	1.4	1.7
High				
MDC	$135/MG	7.1	8.8	9.4
nonMDC	$121/MG	1.4	1.8	2.1
Water Pricing				
Low				
MDC	Insignificant	0	0	0
nonMDC	Insignificant	0	0	0
Moderate				
MDC	$6/MG	0	0.3	2.7
nonMDC	Insignificant	0	0	0
High				
MDC	$4/MG	7.2	7.1	7.0
nonMDC	Insignificant	1.7	1.7	1.8
Tax Incentives	Analysis indicated no signficant water savings could be achieved			
Public Buildings	Estimates included in nondomestic conservation			
Nonemergency Education				
Low				
MDC	$91/MG	4.7	3.1	1.8
nonMDC	$183/MG	1.8	1.3	0.7
Moderate				
MDC	$502/MG	10.7	7.5	4.2
nonMDC	$332/MG	4.2	3.0	1.8
High				
MDC	$914/MG	20.7	15.5	7.5
nonMDC	$485/MG	7.2	5.8	3.6
Potential to Use Nonpotable Water				
Public Financing	$ 70/MG to $1040/MG	4 to 7		

Table 3. Summary of Drought Response Plan

Drought Watch
$ 256,700*

MDC prepares education materials, updates drought plan.

Water Use Reduction		Reservoir Storage Activation	Number of Months Activated
Summer	0%	50% to	6
Winter	0%	46%	

Stage One
$ 3,644,800

Voluntary residential conservation; prepare for Stage Two.

Water Use Reduction		Reservoir Storage Activated	Number of Months Activated
Summer	0.5%	45.5%	30
Winter	0.3%		

Stage Two
$35,753,200

Mandatory outdoor, voluntary indoor conservation; non-residential voluntary conservation; prepare for Stage three.

Water Use Reduction		Reservoir Storage Activated	Number of Months Activated
Summer	6.5%	40.5%	17
Winter	5.0%		

Stage Three
$ 7,463,700

Residential rationing program; mandatory nondomestic program; system leak detection and repair program.

Water Use Reduction		Reservoir Storage Activated	Number of Months Activated
Summer	28.0%	38.0%	4
Winter	32.0%		

TOTAL COSTS

MDC	$ 8,234,100
Local Communities	$38,884,300
TOTAL	$47,118,400

*All costs shown are in 1982 dollars.

program would remain relatively constant over the planning period.

- The average daily water savings for the high level of effort program would be 4.8 MGD at a cost of $267/MG.

- The average daily water savings for the moderate level of effort program would be 4.3 MGD at a cost of $201/MG.

- The average daily water savings for the low level of effort program would be 2.5 MGD at a cost of $92/MG.

- Domestic leak recovery is a long-term program which includes recovering water losses due to leaks in households. The average daily water savings from this program would increase slightly over the planning period as more households are built, which subsequently generate more leakage.

  - The average daily water savings for the high level of effort program would be 8.0 MGD at a cost of $1004/MG.

  - The average daily water savings for the moderate level of effort program would be 2.5 MGD at a cost of $188/MG.

  - The average daily water savings for the low level of effort program would be 1.0 MGD at a cost of $354/MG.

  The effort required to recover substantial portions of domestic leakage is very high, including house-to-house visits by trained personnel (i.e. high level of effort). However, efforts to recover modest portions are much less, thereby causing a substantial decline in unit costs for the moderate and low levels of effort. The low level of effort program is more expensive than the moderate program because it requires relatively more effort to achieve minor water savings.

- Domestic device retrofit is a long-term program which includes reducing domestic use by retrofitting conventional plumbing fixtures with low flow devices. The average daily water savings for this program declines substantially over the planning period due to the effects of the Massachusetts plumbing code, which requires water conserving fixtures in all new construction and renovation

projects. As water users install water saving plumbing fixtures, water savings achieved from retrofit of conventional fixtures declines.

- The average daily water savings for the high level of effort program would be 16.5 MGD at a cost of $235/MG.

- The average daily water savings for the moderate level of effort program would be 4.9 MGD at a cost of $253/MG.

- The average daily water savings for the low level of effort program would be 2.5 MGD at a cost of $128/MG.

The high and moderate levels of effort programs both require substantial MDC and local community participation to succeed. However, the high level of effort program results in significantly more water savings during the first ten years of the planning period than the moderate program. Therefore, unit costs of the high program are less than the moderate program unit costs.

- Nondomestic conservation is a long-term program which includes several elements to encourage reduction of industrial, commercial, government, and institutional water use (cooling, process, and sanitary). Some of these programs include financial subsidies to private companies, which may not now be allowed under MDC statutory authority. The average daily water savings from this program remains relatively constant over the planning period.

  - The average daily water savings of the low level of effort program would be 1.7 MGD with a negligible cost.

  - The average daily water savings for the moderate level of effort program would be 6.8 MGD at a cost of $33/MG.

  - The average daily water savings for the high level of effort program would be 8.8 MGD at a cost of $135/MG.

  These costs do not include direct costs to private companies to implement the program.

- Water pricing is a long-term program which includes increasing water rates to encourage users to save water. The average daily water savings are

negligible because the relative price of water would be too low to be an effective economic incentive. Only the high level of effort program achieves significant water savings, and that level of water pricing, 50 percent above full cost of service, is higher than would likely be approved by local communities. The costs are insignificant because the estimates did not include direct costs to the communities to modify their water rates, or costs to the water users.

- Tax incentives, a long-term program, would offer special tax credits to users who installed water saving equipment. The analysis has shown that this program would not achieve any substantial water savings in the region.

- Public building device retrofit is a long-term program which includes reducing nondomestic use by retrofitting fixtures in public buildings with low flow devices. The water savings and cost of this program are part of the nondomestic water conservation program.

- Nonemergency education, a long-term program, would decrease domestic use by encouraging adoption of water conserving habits and installation of low flow devices. The average daily water savings from this program is highest in 1990 and declines substantially by 2020 due to the effects of the plumbing code.

  - The average daily water savings for the high level of effort program would be 13.0 MGD at a cost of $914/MG.

  - The average daily water savings for the moderate level of effort program would be 6.7 MGD at a cost of $502/MG.

  - The average daily water savings for the low level of effort program would be 2.8 MGD at a cost of $91/MG.

- Use of non-potable water, a long-term program, would reduce demand on the MDC system by encouraging large water users (users which consume over 10 million gallons per year) to switch from using MDC water to using local non-potable sources. Water demand would not decrease, just the amount of water required from the MDC system would decrease. The program designed was based on the assumption that the MDC would construct and operate facilities to provide selected

users with non-potable water. This program may require a change in MDC statutory authority because it would essentially be a direct subsidy to private companies. The cost of the facilities ranges from $70 per million gallons to $1040 per million gallons. The average daily water savings to the MDC system would be 4 to 7 MGD.

- The drought response plan is a short-term program to encourage short-term use reductions only during drought emergencies. Because the MDC system is designed to meet a specified withdrawal rate for only 98 percent of the time, some supply failures are expected. The drought response plan is designed to reduce the 2 percent risk of supply failure and does not affect long-term water demand. It does affect the safe yield of the MDC reservoir system. Safe yield for the MDC system has been defined as the amount of water that can be withdrawn from a water supply system consistently over a period of time (including drought years) without violating water quality or ecological requirements. The total cost of a drought response plan for the existing 44 MDC user communities over the 40 year planning period would be $47,118,400 (in 1982 dollars).

PROGRAM DESIGN

For programs which require the participation of water users' (all domestic and nondomestic programs, except for public building device retrofit), the MDC would have to undertake a program to encourage their cooperation. The level of effort that the MDC would contribute to the program would result in different levels of cooperation and therefore, different water savings. Water savings for user participation programs, as well as pressure reduction, were estimated for three different levels of effort: high, moderate, and low.

- Low level of effort - The objective would be to accelerate implementation of baseline water conservation activities, and program implementation would require minor additional MDC or local community personnel.

- Moderate level of effort - The objective would be to encourage water savings above baseline activities, and program implementation would, in most cases, require additional MDC and local community personnel.

- High level of effort - The objective would be to encourage the maximum level of water savings

possible, and program implementation would require additional MDC and local community personnel.

DERIVATION OF WATER SAVING ESTIMATES AND COSTS

The water savings and cost estimates of the demand management programs were derived using data from the following sources:

- analysis of water use by component from the Water Demand Projections report;
- review of Phase I water conservation findings and conclusions;
- review of literature on each subject area;
- review of similar programs in the MDC planning area;
- review of similar programs from other parts of the country, if similar programs had not been implemented in the MDC planning area;
- interviews with water users, utility superintendents, consulting firms, and other companies, government agencies, and researchers involved in demand management programs throughout the nation; and,
- case studies of communities and water users in the MDC planning area where demand management programs have been implemented.

Derivation of Water Saving Estimates

From review and analysis of the available data, two factors were estimated for most demand management programs:

- the water saving factor, or the amount of water that would be saved on an individual household, business, or community basis; and,
- the response rate, or the percentage of water users that would respond to the program.

Water saving factors and response rates were estimated for each level of effort for most demand management programs based on literature review and case studies of similar programs. For example, after review of the available information, it was estimated that retrofitting a conventional showerhead with a quality low flow showerhead would reduce shower water use by 25 percent.

Therefore, the water saving factor for the shower component of the domestic device retrofit program would be 25 percent. It was also estimated that the response rate for a moderate level of effort domestic device retrofit program would be approximately 30 to 35 percent, i.e. 30 to 35 percent of domestic users in the MDC planning area would install a low flow showerhead in response to the MDC program. Both these factors are then used to calculate water savings as summarized below.

(Response rate) x (number of households) = total number of households responding to program

(Water saving factor) x (shower use per household) = water saved per household

(Total number of households responding) x (water saved per household) = total water saved

(Total water saved x 100) / total water use = percent water saved.

Depending on the level of accuracy or confidentiality of data available, total water savings were estimated either for each community, or for the region as a whole. Despite attempts to calculate all water savings on a community-by-community basis, the available data for some demand management programs were not specific enough to derive water saving factors and response rates applicable to each community. For example, for the domestic leak recovery program, 100 households out of approximately 850,000 in the current MDC area were surveyed. Based on the survey results, an average water loss factor of 9.6 gallons per household per day was derived. This factor, while suitable for extrapolation to determine the order of magnitude of water loss, was not suitable to project water loss on a house-by-house basis because it represents a wide range of losses which did not correlate to any specific household characteristics. Further, there were no other data available on domestic leakage to support the results of the survey. Therefore, to estimate savings for this program on a community-by-community basis would be potentially inaccurate and misleading.

In addition, all nondomestic conservation data are reported on a regional basis to ensure the industries confidentiality specified during the interviews.

Water saving estimates were prepared on a community-by-community basis for pressure reduction, domestic device retrofit, nonemergency education, and drought response programs. Water saving estimates were

prepared on a regional basis for reduction of system leakage (improved system management practices), domestic leak recovery, nondomestic conservation, water pricing, and potential for non-potable water use programs. Water savings for the drought response plan were estimated on a community-by-community basis for MDC communities only.

Derivation of Program Costs

To ensure consistency of data for comparison among the demand management programs, as well as comparison of the final demand management plan to the structural alternatives, the demand management program cost data are calculated by the same method as the structural alternatives. The method is the net present value of total expenditures for the program throughout the planning period. The total net present value is divided by total water saved (or total water yield) over the 40-year planning period to provide a unit cost of water, or net present value/million gallons.

To calculate net present value, the following steps were taken.

- Estimate annual operation and maintenance costs of the program, in 1982 dollars for each year that the program would be activated. For demand management programs, operation and maintenance costs would include MDC and local community personnel to administer and implement the program, materials for education, and miscellaneous expenses, such as warehouse storage for the device retrofit program

- Estimate capital costs, or any cost that would be paid for by bond, in 1982 dollars. For demand management programs, capital costs would include purchase of devices for domestic device retrofit, construction of facilities for nonpotable use of water, funds for nondomestic conservation programs, or funds for communities to implement improved system management practices (i.e. reduction of system leakage).

- Calculate actual annual water yield. Because water savings for most of the demand management programs are not constant over the planning period, the annual water savings will change each year. Water savings for the target years 1990, 2000, and 2020 were estimated as part of the individual program assessments. Water savings for years between target years were calculated assuming that the rate of change between the target years would be constant. For example, if there were a 10 MGD difference

between water savings in 1990 and 2000, it would be assumed that the annual water savings would change by one MGD per year.

- Adjust the annual costs to reflect the influence of inflation, using a rate in the mid-range of most economic forecasts (Data Resources, Inc., Chase Econometrics, and contacts with several local private financial institutions). This inflation rate was a flat rate of 5.5 percent per year. The equation used to adjust an annual cost in some year from the base year (0-year), is the following:

  $$(\text{annual cost}) \times (1 + i)^n$$

  where i = inflation rate, of 5.5 percent and
  n = year of payment, 0 through 38, with year 0 being 1982 and year 38 being 2020.

- Convert the inflated annual costs to present value. Present value equalizes all future costs to represent their value in 1982 dollars. The rate used to discount future costs back to the 1982 present value was assumed to be 8.0 percent, based on the mid-range of several economic forecasts (Data Resources, Inc, Chase Econometrics, and contacts with several local private financial institutions). The equation used to calculate present value is the following:

  $$(\text{inflated annual cost})/(1 + \text{discount rate})^n$$

  where n = year of payment, 0 through 38, with year 0 being 1982 and year 38 being 2020.

- Calculate total cost of the program throughout the planning period. The present value of each year's expenditures are summed to derive the total present value of the program.

- Estimate residual value. Residual value is the original capital cost minus the estimated depreciation from the date the structure was built to the last year in the planning period. The residual value, is estimated in 1982 dollars, then is inflated to the year 38, the last year of the planning study. Then, the inflated cost is discounted back to present value, using year 38 as well.

- Calculate net present value. Net present value is the difference between total present value and the residual present value.

- Calculate unit costs. The unit selected is net present value per million gallons.

- This unit cost is used for an economic analysis to compare the costs of all programs to each other. Another measure of cost is the annual MDC expenditure required to pay for each program. The method to derive this cost is the same method described above, except for capital costs. Any capital cost that would be paid for by a bond would require repayment over a 30 year period. The repayment would be equal annual payments that include interest on the bond. To calculate the annual payments, the following method was used:

  - estimate capital costs in 1982 dollars;

  - determine what the actual cost would be by inflating 1982 cost by 5.5 percent per year to year that bond is floated; and,

  - amortize cost over a 30 year investment period using the following formula

$$\text{(inflated capital cost)} \times \left(i \times (1 + i)^n\right) / (1 + i)^n - 1$$

where i = interest rate, is 8.0, and
n = year bond would be floated, plus 30.

Other assumptions used in the cost method for demand management programs are summarized below.

- All labor rates are based on 1982 MDC rates for similar positions, plus 32.5 percent of the base salary to cover fringe benefits (19 percent of base salary), administrative overhead (8.5 percent), and space use (5 percent).

- Capital costs include estimates for total construction costs, contractors overhead and profit, engineering fees, land and right-of-way purchases, legal/fiscal/administrative fees, and interest payments during construction.

- Operation and maintenance costs include estimates for energy, chemicals, materials, and replacement.

- The period of analysis is between 1982 and 2020.
- All demand management programs would be initiated in 1985.
- All start up costs for demand management programs could be handled by existing MDC personnel and were not included as a separate cost item.
- Any private investment costs would require an 11.0 percent interest rate.
- The MDC currently charges communities a flat rate for water of $240 per million gallons.

INDIVIDUAL PROGRAM SUMMARIES

Summaries of each of the eleven programs are presented and include the water savings and costs of each, if they were implemented in the planning area independently. The summaries also include a qualitative impact analysis and a description of the individual elements that would be required to implement each program.

UNACCOUNTED-FOR WATER AND LEAKAGE RECOVERY WITHIN PLANNING AREA COMMUNITIES

Introduction

This work investigates unaccounted-for water and recoverable leakage in the distribution systems of communities currently served by the MDC and potential future users. Projections of unaccounted-for water are made under two conditions: the first assumes a continuation of existing system management practices; the second assumes improved system management practices. Finally, the costs and benefits of programs to reduce levels of unaccounted-for water are assessed. One associated element of unaccounted-for water, transmission system losses occurring in the MDC system, was also reviewed. This evaluation is included in Appendix 2-D of the Demand Management Interim Technical Report.

Unaccounted-for water in community distribution systems comprises a significant element of total water supplied by the MDC, on the order of 30 percent. Unaccounted-for water is made up of various elements. These include: water main leaks and breaks, meter inaccuracies, unmetered public use, unauthorized connections, and errors in estimates for unmetered consumers. Approximately 25 percent of unaccounted-for water in the community systems is recoverable through leak detection and repair.

25% of 30% or 7½% RECOVERED

The general rules are applied to 1980 metered consumption data to provide estimates of current levels of unaccounted-for water. Projections of unaccounted-for water are made for existing system management practices and for improved system management practices. Detailed cost estimates of existing management practices and implementation of improved system management practices are presented in the Demand Management: Interim Technical Report.

The level of analysis described in this report is regional. While calculations were performed on an individual community basis, the confidence in estimates of the elements of unaccounted-for water for a single community is limited. The precision of estimates for groups of communities (e.g. fully-supplied members) is

considerably higher, and the estimates should provide a sound basis for MDC policy formulation.

MDC Revenue Meter Accuracy

Revenue meters measure the quantity of water delivered by the MDC to each community system. Approximately 161 revenue meters measure flow to the Metropolitan Water District communities. They are of two basic types: venturi and compound.

Accuracy of revenue meters is critical, if accurate estimates of unaccounted-for water are to be provided. Inaccuracies in revenue meters are reflected, gallon-for-gallon, in unaccounted-for water, because unaccounted-for water is essentially the difference between revenue meters and the sum of consumer meters.

The results of accuracy tests performed on many MDC revenue meters between 1976 and the present were reviewed. On the basis of this review it was concluded that significant inaccuracies may exist. The data reviewed were not sufficient to assess whether the overall effect is over- or under-registration. The MDC is currently reconstructing 67 of its largest revenue meters. When data from these new meters become available in 1983 a better assessment of the effect of revenue meter inaccuracy on unaccounted-for water will be possible. For purposes of this study, it is assumed that the revenue meters in the aggregate are accurate, and as such are not a factor in unaccounted-for water.

Domestic Meter Underregistration

In this study, domestic meters are defined as those one inch or less in size. Underregistration is defined as the amount of water that passes through a meter and is not recorded.

To assess the significance of domestic meter underregistration, a meter sampling and testing program was undertaken with the cooperation of a number of currently supplied communities. Over 400 meters were removed from service and tested for accuracy at three rates of flow. The results of the program suggest that domestic meter underregistration for communities in the planning area is between 5 and 6 percent of total domestic flow.

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Nondomestic Meter Underregistration

Nondomestic meter underregistration was assessed primarily by reviewing test reports for as many previously conducted in situ tests as possible. Data from tests conducted in Boston, Massachusetts and Worcester, Massachusetts and supported by the experience of a number of other water systems constituted the basis for the estimate of 10 percent nondomestic meter underregistration.

10%

Unmetered Public Use

Unmetered public use includes the following types of water use:

- water used in fighting fires;
- hydrant use for sewer flushing, water main blowoffs, and street cleaning;
- unauthorized hydrant openings; and,
- main breaks, etc.

The general practice among waterworks officials is to estimate unmetered public use as 1 percent or less of total supply. The analysis used for this study was directed at testing this hypothesis. The analysis consisted of four major steps:

- review of previous discussions with water department superintendents in currently-supplied communities;
- further in-depth discussions with an MDC-supplied community that kept records of water used in fire fighting;
- review of pertinent technical literature; and,
- discussions and evaluation of data from other east coast water utilities.

Most currently-supplied communities did not account for any unmetered public uses. Some communities made estimates and kept records of some unmetered public uses. Some planning area communities were willing to provide estimates of some unmetered public uses. For example, estimates of water usage for fire fighting purposes were obtained from Medford Fire Department which keeps records of estimated water usage on a call-by-call basis. However, the most comprehensive accounting of these uses was provided by the Manchester (New Hampshire) Water

Department. Data from these various sources were assembled and analyzed. It was concluded that 1 percent of total supply is a generally valid estimate of unmetered public use. The exception to this estimate would be for Boston, where high fire use and unauthorized hydrant openings result in an estimate of 3 percent of total supply.

Unavoidable Leakage

Unavoidable leakage is composed of numerous leaks too small to detect. A frequently cited expression for unavoidable leakage is 250 gallons per day per mile of main per inch diameter. This is a modification of an expression, originally derived in 1897 which estimated unavoidable leakage as 2,500 to 3,000 gallons per day per mile.

The objective of this analysis was to assess the validity of these expressions. A literature search was conducted. Staff and committee members of the American Water Works Association (AWWA) were interviewed. Discussions were held with Pitometer Associates, a leading authority on leakage and unaccounted-for water. Also, data from the 1981 AWWA "Water Utility Operating Data Survey" were analyzed.

As a result of these investigations, several points were apparent.

- Some level of system leakage is unavoidable.

- The previously mentioned expressions for unavoidable leakage are in common use.

- While some water supply engineers stated that unavoidable leakage must be determined on a system-by-system basis, no individuals or utilities contacted had estimated unavoidable leakage for their distribution systems.

- When the traditional expressions are applied to urban or suburban water systems, unavoidable leakage generally comprises 5 percent or less of total supply (examples: Boston - 2.3 percent, Everett - 1.9 percent, Malden - 4.5 percent). However, when traditional expressions are applied to water systems in less densely populated communities, unavoidable leakage often exceeds 10 percent, and in the case of one planning area community constituted 28.4 percent of total supply. In this particular community, and in several other planning area communities, unavoidable leakage as calculated by traditional

expressions exceeded total unaccounted-for water (calculated by subtracting accounted-for water from the total supplied to the distribution system).

- A rational expression for unavoidable leakage should not only depend on the length and diameter of pipes, but also on pipe material, system pressure, soil porosity and soil corrosivity.

In the past, unavoidable leakage has been used primarily as a means to calculate recoverable leakage. It had been one of the categories of metered or estimated water use subtracted from total supply to arrive at the remainder: recoverable leakage.

While the traditional expressions for unavoidable leakage are not adequate, a means to calculate recoverable leakage without considering unavoidable leakage as an explicit water use category has been developed for this analysis.

Recoverable Leakage

As indicated, the customary way to estimate recoverable leakage has been to deduct all known and estimated uses of water from the total supplied to a distribution system. This method has been used in the past to provide estimates of potentially recoverable leakage in MDC communities (University of Massachusetts Water Resources Research Center, 1975; Linsky, 1980).

Several planning area communities had conducted leak detection and repair programs in their entire distribution systems in recent years. These communities were identified, and using the traditional method, potentially recoverable leakage was calculated for each community. Concurrently, data were requested from the MDC relative to monthly supply in the 12 months before and after the leak detection and repair program. The decrease in water supplied by the MDC after leak repair was determined. These supply decreases were compared to the values of potentially recoverable leakage computed by the traditional method. Based upon this data, a relationship was developed between potentially recoverable leakage, as traditionally calculated, and decrease in supply, as an actual measurement. This relationship allowed estimates of supply decreases that would result from leak detection and repair to be calculated once certain basic system information was known.

Other Unaccounted-for Water

Certain elements of unaccounted-for water are present in all water distribution systems. However, each water distribution system has certain unique characteristics which result in categories of unaccounted-for water which may not exist in other systems. These may include:

- illegally-tapped fire lines;
- reservoir evaporation and leakage;
- standpipe overflows;
- data processing errors;
- errors in estimates for stopped meters;
- failure to account for public use that may be metered but not billed; and,
- overregistering revenue meters.

Each of these categories may exist in one or more communities, and it is safe to assume that some of these categories occur in all communities. However, a detailed engineering evaluation of each community distribution system would be required to more definitively quantify these elements of unaccounted-for water. Because these detailed engineering evaluations were not completed as part of this current work, it was necessary to establish a general category to accommodate these varied elements of unaccounted-for water. This category is termed "Other Unaccounted-For Water".

Estimates of Unaccounted-For Water

Based upon data from the year 1980, major water use statistics in currently-supplied and potential future user communities are summarized in Table 4, "Summary of Major 1980 Water Use Statistics in Currently Supplied and Potential Future User Communities." Unaccounted-for water is further subdivided in Table 5, "Summary of Unaccounted-For Water in Currently-Supplied and Potential Future User Communities for 1980." These estimates, as well as all other water use statistics, estimates, and projections in this chapter, consider all communities as if they took 100 percent of their water from the MDC.

Table 4. Summary of Major 1980 Water Use Statistics in Currently-Supplied and Potential Future User Communities

Water Use Component Communities	MDC Communities	nonMDC
Total Supplied (By MDC and Local Sources)	369.5 MGD	94.7 MGD
Total Metered	263.7 MGD	73.1 MGD
Total Unaccounted-For	105.9 MGD	21.6 MGD
Metered Ratio	0.71	0.77

Table 5. Summary of Unaccounted-For Water in Currently-Supplied and Potential Future User Communities For 1980

	MDC Communities		nonMDC Communities	
Element of Unaccounted-For Water	MGD	Percent of Total Supply	MGD	Percent of Total Supply
Domestic Meter Underregistration	8.5	2.3	3.0	3.2
Non-Domestic Meter Underregistration	13.4	3.6	2.5	2.6
Unmetered Public Use	6.4	1.7	0.9	1.0
Recoverable Leakage	25.6	6.9	5.0	5.3
Other Unaccounted-For Water (Including Unavoidable Leakage)	52.0	14.1	10.2	10.8
TOTAL	105.9	28.6	21.6	22.9

- Non-domestic meter underregistration decreases from 10 percent to 5 percent by 1990 and remains at that level.

- Unmetered public use decreases by one-third by 2000 and remains at that level.

- Leak detection and repair programs are conducted on all community distribution systems at two-year intervals. The average recoverable leakage over the study period is approximately 6.5 MGD in currently-supplied communities. This reflects leaks that occur between detection and repair programs.

- As with existing system management practices, "Other Unaccounted-For Water" is held constant for the study period.

Projections. When the foregoing assumptions for existing system management practices are applied to the water demand projections (see Water Demand Projections report), the resultant projections of unaccounted-for water are as indicated in Table 6 "Projection of Elements of Unaccounted-For Water - Existing System Management Practices."

Table 6. Projection of Elements of Unaccounted-For Water Existing System Management Practices (Million Gallons Per Day)

Component	1990		2000		2020	
	MDC	Non-MDC	MDC	Non-MDC	MDC	Non-MDC
Domestic Meter Underregistration	7.3	2.8	7.2	3.0	7.5	3.3
Non-Domestic Meter Underregistration	12.7	2.6	13.5	2.9	15.5	3.6
Unmetered Public Use	6.5	1.0	6.5	1.0	7.0	1.2
Recoverable Leakage	9.9	1.8	11.8	3.1	20.0	5.8
Other Unaccounted-For Water	52.0	10.2	52.0	10.2	52.0	10.2
TOTALS	88.4	18.4	91.0	20.2	102.0	24.1

When the assumptions for improved system management practices are applied to the water demand projections (see Water Demand Projections report), the projections of

Projections of Unaccounted-For Water

Unaccounted-for water in currently supplied and potential future user community distribution systems was projected for the years 1990, 2000 and 2020. Projections were made under two sets of conditions: one assumed a continuation of existing system management practices; and the other assumed improved system management practices.

Existing System Management Practices. This condition assumes that existing practices and conditions will continue essentially unchanged, except in cases where a program already in place can be expected to produce some alteration in existing conditions.

An example of such a program is the Massachusetts Leak Detection and System Rehabilitation Program, funded under Chapters 805 and 286 of the Massachusetts General Laws. About half of the fully supplied communities have received grant funds in the first two years of the five-year program. It is assumed that before the program expires, that planning area communities associated with approximately 75 percent of total MDC supply will have received grant funds. The effect of this program is expected to produce a decrease in leakage (and unaccounted-for water and total supply) of approximately 14 MGD between now and 1990. Between 1990 and 2020, a slight increase in leakage is assumed.

Several communities have in place aggressive meter replacement and repair programs. Meter accuracy in these communities is estimated as somewhat higher than the average. This accounts for a slight decrease in unaccounted-for water (3 MGD) but no change in total supply.

The components of "Other Unaccounted-For Water" are largely unquantifiable, and no attempt to project how these miscellaneous factors may change in future years is made; the category is held constant for the study period.

Improved System Management Practices. Improved system management practices are practices which, if effected, would result in minimum levels of unaccounted-for water, giving due consideration to economics, system age, and climatic conditions.

Specific assumptions are summarized below.

- Domestic meter underregistration decreases from 5.6 percent to 3 percent and remains at that level.

unaccounted-for water are as indicated in Table 7, "Projection of Elements of Unaccounted-For Water - Improved System Management Practices".

Table 7. Projection of Elements of Unaccounted-For Water Improved System Management Practices (Million Gallons Per Day)

Component	1990		2000		2020	
	MDC	Non-MDC	MDC	Non-MDC	MDC	Non-MDC
Domestic Meter Underregistration	4.3	1.6	4.2	1.6	4.4	1.8
Non-Domestic Meter Underregistration	6.9	1.3	7.3	1.4	8.3	1.7
Unmetered Public Use	5.3	0.8	4.3	0.7	4.7	0.8
Recoverable Leakage	6.5	1.3	6.5	1.3	6.5	1.3
Other Unaccounted-For Water	52.0	10.2	52.0	10.2	52.0	10.2
TOTALS	75.0	15.2	74.3	15.2	75.9	15.8

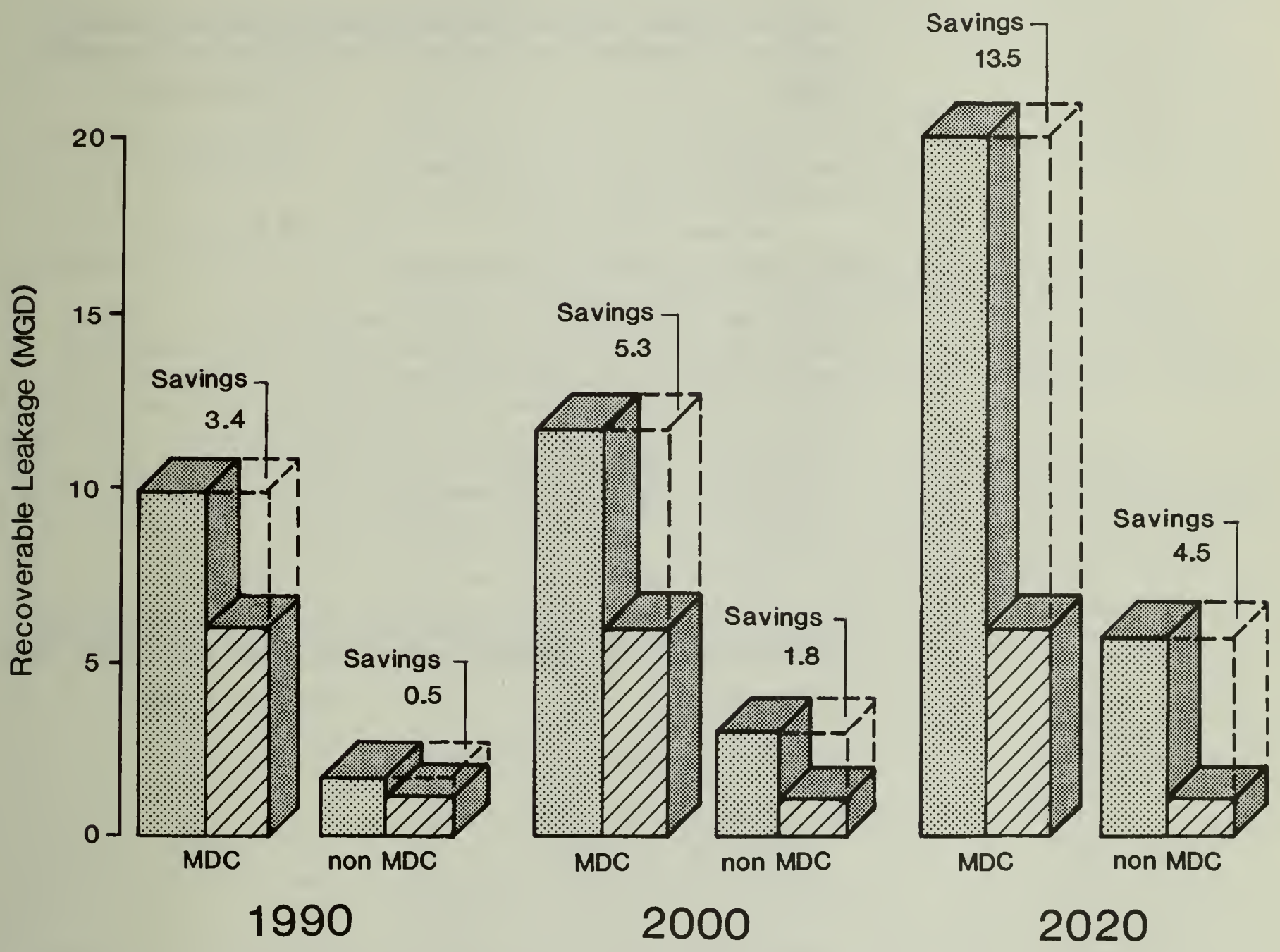
Water Savings Due to Improved System Management Practices. As can be seen by comparing Table 6 with Table 7, improved system management practices will result in reduced levels of unaccounted-for water in 1990, 2000, and 2020. These water savings reflect the difference in water use at two levels - existing system management practices and improved system management practices. However, only the reductions in recoverable leakage will result in actual water savings. Reductions in domestic and nondomestic meter underregistration and unmetered public use are offset by equal increases in the metered use projections.

If improved system management practices are implemented, the water savings due to reductions in recoverable leakage will be 3.9 MGD in 1990, 7.1 MGD in 2000, and 18.0 MGD in 2020. These results are shown in Figure 1, "Water Savings as a Result of Improved System Management Practices".

Costs of Leak Detection and Repair Associated With Improved System Management Practices

It is estimated that two complete leak detection and repair programs separated by one year will be required to reduce recoverable leakage to approximately zero. Subsequently, programs will be required every two years. The direct costs in 1982 dollars to conduct these programs in currently supplied, and potential future user communities

Figure 1.
Water Savings as a Result of Improved System Management Practices



Balance of Recoverable Leakage Under Existing System Management Practices

Balance of Recoverable Leakage Under Improved System Management Practices*

Cost of Improved System Management Practices:
MDC - $261/MG nonMDC - $293/MG

*The balance of recoverable leakage represents a two-year average between year one of the leak detection and repair program, when the balance is zero for both MDC and nonMDC communities, and year two of the program, when leakage recurs to 13.0 MGD for MDC communities and 2.6 MGD for nonMDC communities.

are shown in Tables 8 and 9, respectively. The accuracy of these cost estimates is judged to be ±30 percent.

Table 8. Program Costs for Leak Detection and Repair, Improved System Management Practices for Currently Supplied Communities

Component	Estimated Cost
Detection & repair at year 1	$2,515,000
Detection & repair at year 2	$2,200,000
Detection & repair each subsequent 2 years	$2,130,000

Using the components of costs from Table 8, the total annual program cost for leak detection and repair under improved system management practices is estimated to be $1,270,700 per year. This is equivalent to approximately $210 per mile of main per year. Alternatively, this may be expressed as $3,440 per MGD of total supply per year. The total net present value would be $261 per million gallons of water saved over the planning period.

Table 9. Program Costs For Leak Detection and Repair, Improved System Management Practices for Potential Future User Communities

Component	Estimated Cost
Detection & repair at year 1	$ 932,500
Detection & repair each subsequent 2 years	$ 775,000

Using the costs from Table 9, the total annual program cost for leak detection and repair under improved system management practices is estimated to be $432,330. This is equivalent to approximately $140 per mile of main per year. Alternatively, this may be expressed as $4,570 per MGD of total supply per year. The total net present value would be $293 per million gallons.

Indirect Costs and Benefits. In addition to the direct costs and benefits, there are a number of indirect costs and benefits associated with leak detection and repair programs. Indirect costs include dust, noise and traffic control during repair, and program administration. Indirect benefits include possible deferred capital outlay for new supply, decreased costs of pumping and chemicals, and decrease in main breaks and others.

Implementation Problems. There should be very few implementation problems associated with a leak detection

and repair program. The MDC's involvement would be to provide funds to the communities for this work and, if necessary, provide training in the use of leak detection and repair equipment to water department personnel in the communities which decide to perform their own work. The communities should be receptive to a leak detection and repair program which is partially or fully funded by the MDC. This was evident in the overwhelming response to the Chapter 286 and 805 grant programs. Furthermore, the benefits to leak detection and repair should motivate the communities to participate in this program.

Costs and Benefits - Meter Repair and Replacement Associated with Improved System Management Practices. Domestic meter underregistration in currently-supplied communities is estimated at 5.6 percent of domestic flow, or 8.5 MGD. In potential future user communities, domestic meter underregistration is estimated as 3.0 MGD.

An aggressive meter replacement program would not be expected to account for all of this underregistration; for practical reasons, some meter inaccuracy is to be expected in even the most well managed systems. A value of 3.0 percent for domestic meter underregistration has been selected as an appropriate objective under "improved system management practices". Literature review and technical inquiries suggested that this percentage was a desirable and attainable level of performance. Attempting to reduce domestic meter underregistration below 3.0 percent would be expected to result in meter replacement costs in excess of the benefits of improved metering. On this basis, the annual unrealized revenues from domestic meter underregistration are estimated to be approximately $2.0 million in currently supplied communities, and $700,000 in potential future user communities. The total cost of a meter replacement program to capture these unrealized revenues in currently supplied communities is estimated as approximately $2.5 million per year. In potential future user communities, this cost is estimated as approximately $0.9 million.

The estimates of costs and benefits are based on the average of 5.6 percent meter underregistration for all currently supplied and partially supplied communities. Undoubtedly, there are individual communities whose domestic meter underregistration exceeds 5.6 percent for which the unrealized revenue would exceed the costs of the replacement program.

Nondomestic meter underregistration in currently supplied communities is estimated at 10.0 percent of nondomestic flow, or 13.4 MGD. In potential future user communities,

nondomestic meter underregistration is estimated as 2.5 MGD.

As with domestic meters, an aggressive meter inspection, calibration, and repair program would not be expected to account for all underregistration. A value of 5.0 percent for nondomestic meter underregistration has been selected as an appropriate objective under improved system management practices. Based on a review of literature and other technical inquiries, 5.0 percent underregistration represents an appropriate objective for improved system management practices. It is believed that attempts to reduce levels significantly below 5.0 percent would not be economically justified. On this basis, the annual unrealized revenues from nondomestic meter underregistration are estimated to be approximately $3.4 million in currently-supplied communities, and $650,000 in potential future user communities. An inspection, repair, and calibration program for the 1000 largest meters in currently supplied communities would be expected to provide the 5.0 percent underregistration. The annual cost of such a program is estimated at $500,000. In potential future user communities, the annual cost is estimated at $94,000.

Implementation Problems. Because meter replacement and repair yields no water savings nor provides any long-term revenues to the communities, there may be problems in convincing the communities to implement this program. While this program has substantial direct costs, it has no real benefits other than to increase meter accuracy which results in a more equitable distribution of costs to the water users. The water departments in the communities may be reluctant to undertake a rigorous meter repair and replacement program (above their existing maintenance practices) because it would require the addition of personnel to their maintenance staffs and training of those personnel in meter maintenance practices. In addition, it may require more maintenance shop space and more storage space for new meters and meter parts.

Other implications of this program are the possible inconveniences to the water users while meter repair work is being conducted.

PRESSURE REDUCTION

A pressure reduction program would result in an immediate water savings which would remain constant, assuming no major changes to the system use or the physical characteristics of the affected water distribution systems.

This study estimated the costs and benefits of implementing such programs in current and potential future user

communities. It was assumed that pressure reduction would be accomplished by placing pressure reducing valves in public water mains, not in individual service connections. Areas were identified in the MDC user communities where system pressures may be sufficiently high to justify a pressure reduction program. Potential water savings and costs were then estimated for three pressure reduction programs at three levels-of-effort.

- Low level-of-effort: pressures greater than 80 pounds per square inch (psi) would be reduced to 60 psi in all communities where the potential water savings is greater than 5,000 gallons/day/valve.

- Moderate level-of-effort: pressures greater than 80 psi would be reduced to 60 psi in all communities where the potential water savings is greater than 2,000 gallons/day/valve.

- High level-of-effort: pressures greater than 80 psi would be reduced to 60 psi in all communities where system pressures may be sufficiently high to justify a pressure reduction program.

The work estimated the costs and benefits of pressure reduction in the MDC communities based on an evaluation of available information. It should not be construed as a detailed engineering analysis. Instead, it is a preliminary screening of MDC communities (for which sufficient data were available), resulting in the identification of areas where pressure reduction appears to be feasible and the associated costs and benefits. Prior to developing definitive estimates of the costs and benefits of pressure reduction for these areas, detailed engineering (water system network) analysis for each community would be necessary. The costs of that level of analysis have not been included in the estimates presented in this report.

Results of this study indicate the following for the current MDC communities studied.

- A low level-of-effort pressure reduction program has the potential to save 2.5 million gallons per day (MGD) at a net present value cost of $92/million gallons (MG).

- A moderate level-of-effort pressure reduction program has the potential to save 4.3 MGD at a net present value cost of $201/MG. The 1.8 MGD over that saved in the low level-of-effort program costs $330/MG.

- A high level-of-effort pressure reduction program has the potential to save 4.8 MGD at a net present value cost of $267/MG. The 0.5 MGD over that saved in the moderate level-of-effort program costs $913/MG.

Results also indicate that there is the potential to save 1.7 MGD from pressure reduction in the potential future user communities.

Because the available information was limited, there may be local community system conditions which would preclude the implementation of pressure reduction to the extent estimated in this study. Some of those conditions are:

- the need to maintain high pressure to overcome high friction losses in water distribution systems caused by tuberculation of pipes or inadequate pipe sizing;

- the need to maintain high pressure to supply water to special users requiring high pressures (certain industries, high-rise buildings, etc.); and,

- the need to maintain high pressure for fighting fires. (Although a pressure reducing valve decreases system pressure, it does not reduce the amount of water available in the system.)

Because pressure reduction would be implemented in the community distribution systems, the MDC may have difficulties implementing the program. The MDC would have to rely on the communities' agreement and commitment to the program. Some communities may be reluctant to implement the program because high pressure may be preferable to maintain because of the local system conditions. Undoubtedly, a grant program would be required to provide adequate incentive to the communities to perform a detailed system analysis and implement a pressure reduction program.

Water savings through implementation of a pressure reduction program could be realized approximately one year after appropriation of funds to the communities. A detailed system analysis, identification of areas where pressure reduction is possible and detailed engineering for installation of pressure reducing valves could be performed within six months. Installation of the pressure reducing valves could be accomplished within another six months.

DOMESTIC LEAK RECOVERY PROGRAM

All water lost within households (i.e. after it has passed through the service meter) is considered domestic leakage. Although domestic leakage has never been quantified, it has been estimated to be significant. The

statistical analysis of results of a survey of one hundred homes in the MDC area indicated that domestic leakage could be significant: approximately 10.6 million gallons per day (MGD) of water could be lost in the planning area (existing MDC user communities and potential future user communities). Leakage was estimated to increase to approximately 12.7 MGD in the planning area as new homes are constructed (the rate of leakage was assumed not to increase, just the total number of leaks).

According to leakage patterns estimated from the survey results, approximately 62 percent could be recovered by replacement of washers in faucets and spigots. Approximately another 32 percent could be recovered by a simple adjustment of the toilet float ball level. The remaining 6 percent would require more complicated replacement of toilet flush valves.

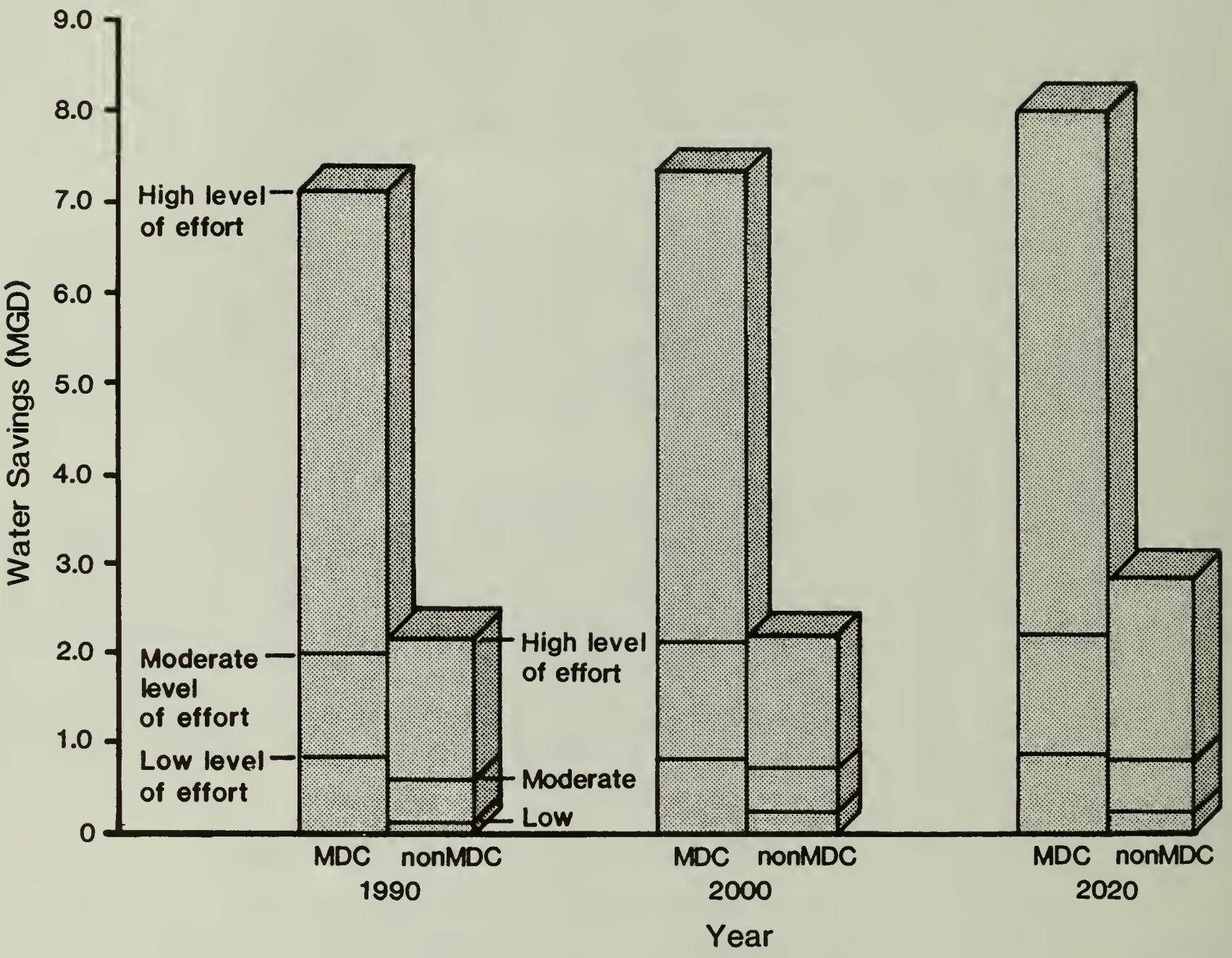
To recover the majority of that leakage, MDC personnel would have to implement a high level of effort program which includes conducting house to house surveys and leak repairs. Lesser efforts rely on homeowners to complete repairs themselves, resulting in lower repair rates and lower leakage recovery. A summary of the three levels of effort programs is presented in Figure 2, "Summary of Domestic Leak Recovery Program". Water savings and costs were calculated for the 44 MDC user communities, referred to as "MDC", and 36 potential future user communities, referred to as "nonMDC".

Plumbing Code Effect on Long Term Savings

In 1978, the Massachusetts plumbing code was changed to require that plumbing fixtures installed in new construction or renovation are water conserving models. The effect of the plumbing code on water use was analyzed as part of the water demand projections (see Water Demand Projections report) and was estimated to result in a lower domestic water use factor by the end of the planning period.

The effects of the plumbing code would, however, not affect long-term savings expected from domestic leak recovery programs. The survey results showed no indication that low flow plumbing fixtures tended to leak less than standard fixtures; nor that age of plumbing fixture correlated with leakage. Therefore, the replacement of old and/or standard plumbing fixtures should not reduce potential leakage, nor would savings expected from repair of leaks be reduced.

Figure 2.
Summary of Domestic Leak Recovery Program



High Level of Effort:

Cost MDC $1004/MG
nonMDC 949/MG

House-to-house surveys and leak repair.

Moderate Level of Effort:

Cost MDC $ 188/MG
nonMDC 195/MG

Local depots and centers to provide materials which encourage leak repair.

Low Level of Effort:

Cost MDC $ 354/MG
nonMDC 264/MG

Education program to encourage leak repair.

Impacts

The major negative impact of this program would be the difficulties the MDC might experience in the implementation of the high and moderate levels of effort programs. These programs are very labor intensive and would require significant new staff positions, or the subsidization of local community personnel to complete the work.

Another major impact would be the cost of the high level of effort program. It is one of the most expensive demand management programs, and could have substantial financial impacts.

The levels of reduction expected would probably not be substantial enough to affect wastewater flows. Community or MDC revenues would not be affected significantly because most leakage, occurring at a very low flow rate, is not recorded by the meter.

Other major considerations are related to implementation of the high level of effort program, which includes in-home leak surveys and repair, when necessary. If this program were implemented, personnel would be entering homes and working with plumbing fixtures throughout the house. The problem of liability for possible damage while working in the house could be minimized with proper insurance coverage and limitation of leak repair to households which grant prior approval. The costs of the high level of effort program included insurance coverage, and the water saving estimates assumed prior approval by the residents.

Derivation of Water Saving Estimates

Water savings for domestic leak recovery were estimated using two factors: the water saving factor, or how much water could be saved in a household after leaks were repaired; and the response factor, or how many households would respond to the programs. These factors were developed by the following tasks:

- conducted a survey of 100 households in the MDC area to determine how much water is lost due to leakage;
- analyzed results of the survey to determine the average amount of water lost on a household basis, or the water saving factor;
- designed programs which the MDC could implement to encourage leak repair; and,

- estimated the percentage of households that would respond to the MDC leak recovery programs, i.e. the response factor.

The confidence interval analysis to assess the reliability of survey results, indicated that the estimates of domestic leakage were not accurate enough to be calculated on a community-by-community basis. Therefore, water savings were calculated on a regional basis, using projections of measured water losses according to different types of leaks (including toilet leaks, faucet leaks, pipe leaks, and shower/tub leaks). It was assumed that once a leak is repaired that all water loss from that leak would be recovered. For example, if 85 percent of the faucet leaks were repaired, then 85 percent of water loss from faucet leaks would be recovered. The program would be repeated periodically to capture new and/or recurring leaks and to ensure that the overall amount of water recovered would remain relatively constant over the planning period.

Derivation of Water Saving Factor

It is estimated that the average daily water loss in the MDC from domestic leakage is approximately 8.3 MGD, or an average of 9.64 gallons per household per day (gphd).

These estimates were based on the sample survey of 100 housing units. The survey revealed that leakage in toilets, sinks, faucets, bathtubs, showerheads, and outdoor spigots in the 100 sample homes amounted to a total of 964 gallons per day. If the survey were assumed to be a randomly selected representative sample of the entire study area, the results indicated that total domestic leakage in the planning area is between approximately 6.1 and 14.7 MGD, with a .80 level of confidence. In fact, because volunteers were used in the survey, the sample was not randomly selected. The influence of this on survey results cannot be quantified, but probably is not significant considering the size of the sample.

The daily household leakage factor was extrapolated to the existing MDC service area by multiplying the daily leakage rate by the number of households, or 9.64 gallons per household per day times 865,500 households. The average daily leakage in 1980 for the MDC was estimated to be approximately 8.3 MGD. When extrapolated to the full planning area (current MDC user communities and potential future user communities), the average daily leakage was estimated to be approximately 10.6 MGD. It was assumed that the leakage rate would remain constant over the study period. To project future leakage, the

9.64 gallons per household per day was multiplied by the number of households projected for each target year (see Water Demand Projections report), the results of which are summarized in Table 10, "Projected Domestic Leakage".

Table 10. Projected Domestic Leakage , in MGD

	1980	1990	2000	2020
MDC	8.3	8.4	8.7	9.4
NonMDC	2.3	2.6	2.9	3.3

Derivation of Response Rate

The leak repair rate, or response factor, would depend on the level of domestic users' response to the three levels of effort programs. There have been no known programs implemented in the country that have focused entirely on domestic leak recovery. Therefore, there was no direct way to estimate consumers' response. However, the programs designed would be similar to the device retrofit programs (see section on Domestic Device Retrofit). A high level of effort program would include house-to-house work; a moderate level of effort program would include direct assistance to users supported by a comprehensive education program; and the low level of effort would include a focused education program on domestic leakage. It is likely that response rates for the domestic device retrofit programs would also be appropriate to the leak recovery programs (see section on Domestic Device Retrofit). The response rates are summarized below.

PROGRAM	AVERAGE RESPONSE RATE
High Level of Effort MDC personnel conduct household surveys and repair leaks where necessary	85%
Moderate Level of Effort Local depots set up to provide materials and information on "easy-to-repair" leaks	25%
Low Level of Effort Education program focused on leak detection and repair	10%

Derivation of Cost Estimates

All labor costs for publicly supported personnel are based on 1982 MDC and local community salaries for similar positions, plus 32.5 percent of base salary for benefits. All other program costs (consultant fees, materials, office rental, transportation, reproduction, and postage) are based on 1982 costs for similar services and products.

The net present value (NPV) of the total program costs were calculated for each level of effort. The net present value figure represents the 1982 value of the cost of the program over the 40-year planning period. It incorporates a 5.5 percent factor for inflation, an 8 percent discount rate, and 8 percent interest on any capital expenditure that would be paid for by a bond.

Program Design

The programs for domestic leakage recovery would be very similar to domestic device retrofit programs (see Domestic Device Retrofit section). The major difference is that the leak recovery programs would be repeated every five years to capture new or recurring leaks.

The high level of effort program was designed to recover the majority of domestic leakage by conducting house-to-house leak surveys and repairs, where necessary. The moderate level of effort program would focus on encouraging homeowners to recover water from easy-to-repair leaks, such as faucet drips and faulty toilet tank float balls using local "depots" to distribute information and basic equipment, such as washers for faucets. The low level of effort would rely primarily on a public education program focused on reducing leakage.

DOMESTIC DEVICE RETROFIT

Water Savings and Cost Estimates

Standard plumbing fixtures can be modified to use less water with special water saving devices, commonly referred to as retrofit devices which are designed for installation in existing fixtures. The most frequently used retrofit devices to date have been items which can easily be adapted to conventional fixtures in the home and which do not alter the day-to-day use of the fixture. These items include low-flow showerhead, toilet tank water displacement items (plastic bottles, plastic bags, dams), and faucet aerators. Once durable water saving

devices are installed, saving water requires little effort by the consumer. The cost estimates indicate that domestic device retrofit may be one of the least expensive domestic water conservation programs studied. Water savings and costs of three levels of effort programs for the 44 current MDC communities, "MDC", and the 36 nonMDC communities, "nonMDC", are summarized below in Figure 3, "Domestic Device Retrofit Summary".

Plumbing Code Affects Long-Term Water Savings

The Massachusetts plumbing code was revised in 1979 to require that all plumbing fixtures sold in the state meet maximum flow rates that are lower than existing standard equipment. This requirement means that new plumbing fixtures could achieve equal and possibly more savings than standard equipment that has been retrofitted. For instance, the plumbing code requires that toilets have a maximum of 3.5 gallons per flush, while standard toilets usually use 5 to 6 gallons per flush. Retrofit of standard toilets with plastic bottles for toilet tank water displacement would save only .5 gallons per flush.

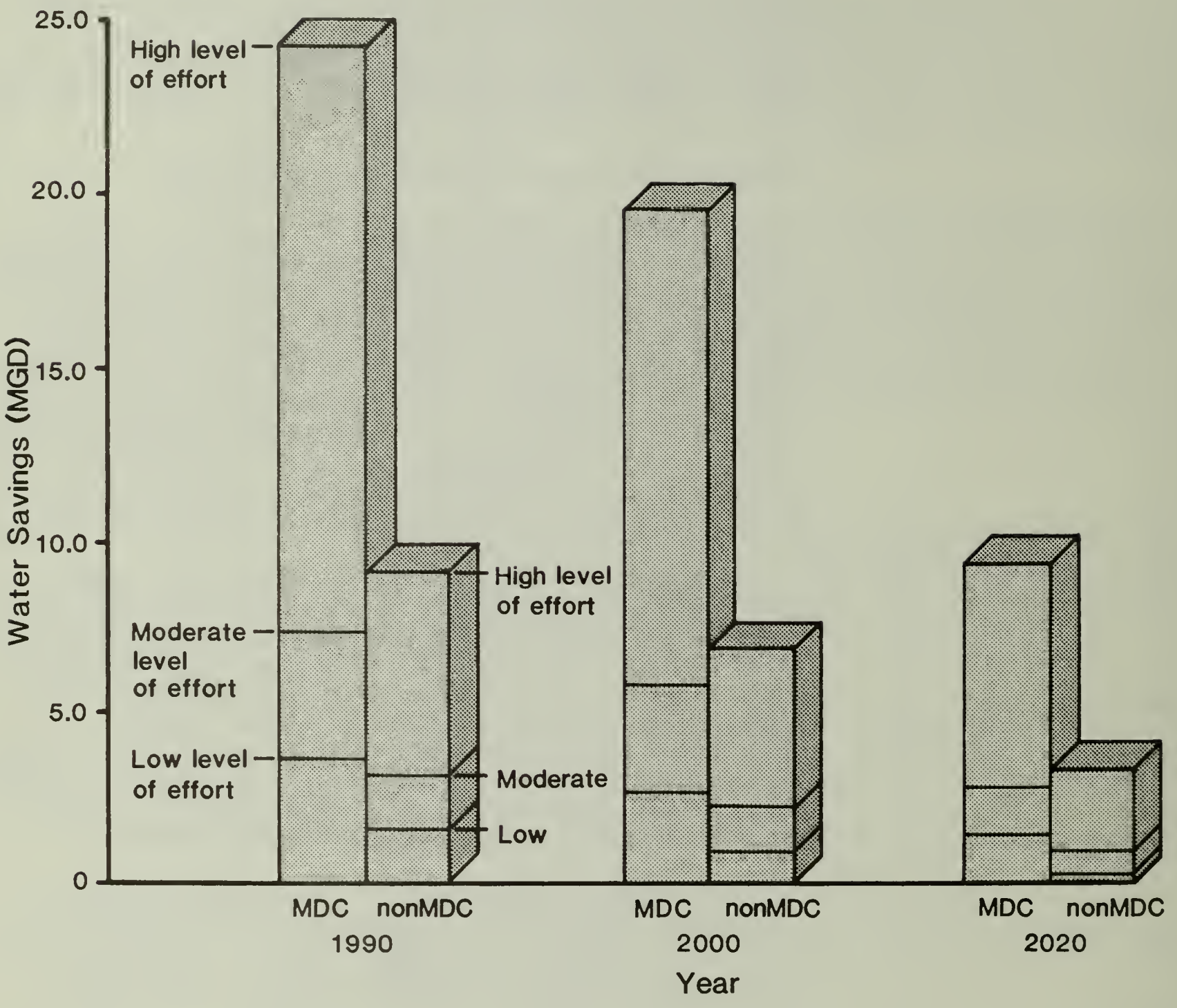
As Massachusetts homeowners rehabilitate and remodel their bathrooms, or replace specific fixtures with new water saving equipment required by the plumbing code, water savings from retrofit of standard equipment would decline. The net effect would still be a decline in average water use but the portion of the decline contributed by retrofit devices would be smaller. If the new plumbing code were not in effect, then water savings from the device retrofit program would remain at more consistent levels throughout the planning period.

The Massachusetts Department of Environmental Quality Engineering (DEQE) is now implementing a $1,000,000 grant program for public water supply agencies to purchase water saving devices for domestic users. The devices would then be sold, at cost, to community residents. Although this program could be expected to accelerate domestic baseline water conservation activities, the results of the program were not incorporated into the water savings projections because it was not in effect at the time this element of the study was being prepared.

Impacts

The major impact of this program would be the difficulties the MDC might experience in the implementation of the high and moderate levels of effort. These programs are very labor intensive, requiring many

Figure 3.
Domestic Device Retrofit Summary



High Level of Effort:	Cost MDC	$ 235/MG
	nonMDC	215/MG

Purchase and install devices in homes.

Moderate Level of Effort:	Cost MDC	$ 253/MG
	nonMDC	215/MG

Purchase and distribute devices via depots and centers.

Low Level of Effort:	Cost MDC	$ 128/MG
	nonMDC	93/MG

Education program to encourage device installation.

new staff positions, or the subsidization of local community personnel to complete the work.

Another significant impact of a long-term device retrofit program would be that it reduces the users' flexibility to respond to short-term water crises. Because this retrofit program would include devices which are easy to install, then such easy measures would no longer be implementable during a drought. To achieve additional savings during an extreme water emergency, extraordinary measures would then be required.

The indoor water saving devices should reduce wastewater flow in proportion to water saved. However, the total quantity of water saved would not be expected to significantly reduce wastewater flows to the MDC sewer system. For those users not part of the MDC sewer system or who are still using on-lot disposal systems, then some improvement in operation of those systems might be expected.

Water revenues to each community and the MDC would drop if significant water savings were achieved. For MDC communities, these decreases might be balanced by the subsequent decrease in their payments to the MDC. For nonMDC communities, the range of savings, by community, shows that those which are primarily residential may suffer a substantial drop in revenues that might have to be compensated for by an increase in the water rate. For those with a mix of residential and nonresidential users, the drop in water revenues could be insignificant. For the MDC, water revenues overall would drop, but may not be significant enough to cause a rate increase or budget adjustment.

The range of water savings for nonMDC communities also indicates that some of these communities projected to experience future water supply deficits may be able to avoid a deficit through such programs. If these deficit communities did not need additional supply from the MDC, then future demand on the MDC system would be reduced.

Other considerations related to the implementation of the high level of effort include distribution and installation of devices. If this program were implemented, personnel would be entering homes and installing water saving devices. The major problem would be liability for possible damage while working in the house. This problem could be minimized with proper insurance coverage and limitation of installation to households that have granted prior approval. Insurance costs are included as part of the high level of effort

program, and water saving estimates reflect volunteer households.

Derivation of Water Savings Estimates

The range of retrofit devices available and their potential to reduce use is wide. Devices range from simple aerators that reduce faucet use by one gallon per minute to waterless toilets that rely on recirculating fluids to evacuate wastes. However, devices which are appropriate for wide-scale use for retrofit of standard plumbing fixtures are somewhat more limited. Because a domestic device retrofit program in the MDC would be wide scale, only those devices suitable for such programs were considered.

To estimate water savings from a device retrofit program, two factors were derived: the water saving factor, or how much water could be saved in a household after water saving devices were installed; and the response factor, or how many households would respond to the programs. To develop these factors, the following analyses were completed:

- selected water saving devices that are appropriate for use in the MDC region;

- determined how much water can be saved within households once these devices are installed (the water saving factor) by reviewing laboratory and field test data of similar devices and by reviewing water use patterns analyzed for the Water Demand Projections report;

- designed programs which the MDC would implement to encourage installation of the devices; and

- estimated the percentage of households that would respond to the MDC device retrofit programs (response factor) by reviewing similar programs implemented in Massachusetts and the country, and by reviewing baseline water use patterns analyzed for the Water Demand Projections report.

Then the water saving factor was multiplied by the response rate for each community to estimate total water savings within each community. Community water savings were added to derive water savings for the existing MDC water users, and for potential future user communities.

Selection of Appropriate Water Saving Devices

To maximize the installation rate of water saving devices, the MDC should select items that most water users would be willing to accept in their homes and use over the long term. As described in the Phase I study, devices which fall into these categories must fulfill the following criteria:

- easy to maintain;
- look and operate like standard equipment;
- adaptable to most standard plumbing fixtures;
- cost should not be excessive;
- easy to install;
- durable; and
- achieve substantial savings.

The water consumption patterns for the MDC area (see Water Demand Projections report) indicate that domestic users will continue to consume a significant amount of water for bathroom uses. Therefore, the primary emphasis of the device selection procedure was on devices related to bathroom use. Research of test programs and field experience consistently show that substantial water savings can be achieved, but the selection of the particular retrofit device must be prudent. Some devices can result in increased water use, if not carefully maintained. A review and analysis of case studies concluded that the most appropriate devices for the MDC area would be low flow showerheads, plastic bottles or bags for toilet tank water displacement, and faucet aerators.

Derivation of Water Saving Factors for Selected Devices

The water saving factor for the device retrofit program was derived to represent the average water savings that would result from the installation of the selected retrofit devices in a household. First, water savings reported in the literature for individual retrofit devices as well as overall household use after retrofit devices were installed, were reviewed to determine the average percentage reduction of baseline water use for a household. Then, the average percentage reduction was compared against the water consumption patterns projected for MDC domestic users (see Water Demand Projections report) to determine if water savings reported in the literature could be achieved in the MDC area.

Derivation of Response Rates

The other factor used to estimate total water savings in a community is the response factor, or how many households would install water saving devices in response to the MDC programs. The response factors were derived from reviewing reports of similar programs and modifying those reported rates according to the individual characteristics of each MDC and nonMDC community.

The results of community-wide retrofit programs vary significantly due to the different methods of distribution, the devices that were used, the circumstances of the distribution (i.e. drought-related or not), and other conservation programs that were in place at time of distribution. Based on programs completed in the Boston metropolitan area (Stoughton and North Reading), and confirmed by similar programs in other parts of the country, the MDC could expect relatively high installation rates throughout the district because the programs to distribute the devices were designed to be responsive to the different needs of the MDC communities. For instance, a distribution program relying on users picking up devices at depots would be done only in areas where this techniques has been shown to be effective. The expected rates for the MDC in general, are summarized below.

High Level of Effort

- 85 to 90 percent for communities that have primarily single-family households.

- 65 to 75 percent for communities that have primarily multi-family households, or for communities (either primarily single- or multi-family households) which have implemented similar conservation programs.

Moderate Level of Effort

- 25 to 35 percent for communities that have primarily single-family households.

- 10 to 15 percent for communities which have primarily multi-family households or communities (either primarily single- or multi-family households) which have implemented similar conservation programs.

Low Level of Effort

- 5 to 15 percent for communities which have primarily single-family households.

- 2 to 5 percent for communities which have primarily multi-family residents or communities (either primarily single- or multi-family households) which have implemented similar water conservation programs.

Derivation of Cost Estimates

The average cost for the recommended device retrofit package of a chrome-plated brass showerhead, two plastic bottles, faucet aerator, and hose attachment is $10.00. This price assumes a large volume purchase of over 100,000 packages and is based on the average from quoted prices received from plumbing fixture manufacturers and distributors, and special organizations which sell only water conserving devices. All companies contacted included special discounts for large volume purchase.

All labor costs for publicly supported personnel are based on 1982 MDC and local community salaries for similar positions, plus 32.5 percent of base salary for benefits. All other program costs (consultant fees, materials, office rental, transportation, reproduction, and postage) are based on 1982 costs for similar services and products.

The net present value (NPV) of the total program costs were calculated for each level of effort. The net present value figure represents the 1982 value of the cost of the program over the 40-year planning period. It incorporates a 5.5 percent factor for inflation, an 8 percent discount rate, and an 8 percent interest on any capital expenditure that would be paid for by bond.

Program Design

The three level of effort programs are designed to encourage installation of the same water saving devices: plastic bottles for toilet tank water displacement, low flow showerheads, faucet aerators, and hose attachments for those residents who could reduce outdoor use. The programs vary according to how installation would be encouraged: for the high level of effort, the MDC would purchase and install water saving devices; for the moderate level of effort, the MDC would purchase and distribute devices; and for the low level of effort, the MDC would sell devices at cost and implement a public education program to encourage residents to install them.

An education program would be important to the success of a device program. For the high level of effort, the education campaign would focus on announcing the program and encouraging participation; for the moderate level of effort, education would announce distribution centers and encourage residents to pick up their devices and install them; and for the low level of effort, the education program would provide information on where to buy devices, and on how to install them.

To maximize installation rates, special efforts for communities with large portions of multi-family dwellings would be required. The education program would include materials that are designed specifically to encourage apartment residents to participate in the program, and distribution techniques would be modified.

NONDOMESTIC CONSERVATION

The water conservation experiences of nondomestic users served as the bases for estimates of future nondomestic water conservation. These estimates include evaluations of three levels of conservation efforts, which are summarized below.

- Relatively low cost efforts which result in reduced process and cooling water use and can be combined with routine maintenance activities. Many large users have already recognized and implemented such measures, with significant results. Other large users and many small users have not recognized or are unaware of the full benefits of such measures.

  This group is the target of the education, technology transfer, and enforcement elements of the low and moderate level demand management programs. Modest conservation potential has been identified in this area.

- Relatively high cost, major capital investment projects to reduce cooling water use implemented by nondomestic users. These projects must be cost justifiable, which according to private investment criteria, requires a pay back period of five years or less. However, many companies currently require a threshold of a shorter payback period in their investment decisions. The conservation potential of those larger capital projects (cooling related) has been estimated assuming the MDC or other funding agency was to provide the difference between cost justification (based on a five-year payback) and project implementation.

- The greatest sanitary conservation potential is in nonmanufacturing establishments, although there is limited potential with manufacturers. This assessment compared the effects of installing retrofit devices (concentrated in the short term) to the effects of replacing sanitary fixtures, in compliance with the new plumbing code (spread over the longer term).

To estimate the conservation potential associated with the three levels of demand management programs, the following factors were considered:

- the type of nondomestic user (manufacturing, nonmanufacturing);
- the size of water use (major user, minor user);
- the type of water use (sanitary, process, and cooling) by user groups, and anticipated change in use patterns; and,
- the anticipated effectiveness and responsiveness of users to the demand management programs.

Manufacturing establishments use water differently than nonmanufacturers: the former use over 90 percent of their water in process and cooling applications; the latter use 80 percent of their water in sanitary applications. Within the MDC, 403 major users in both categories account for more than half of nondomestic water use and represent a concentrated group towards which demand management strategies can be targeted. Based on the major user survey, nondomestic case studies, MDC and municipal water department records, and other local information, the proportion of manufacturing water consumed by major and minor users in different applications was determined.

- Nearly 70 percent of all water used in process and cooling applications by manufacturers was consumed by major users and about 30 percent by minor users.
- About 45 percent of all sanitary water used by manufacturers was consumed by major users and 55 percent by minor users.

For nonmanufacturing users, it was determined that:

- about 49 percent of all cooling water used by nonmanufacturing establishments was consumed by major users and 51 percent by minor users; and,

- about 49 percent of all sanitary water used by nonmanufacturing establishments was consumed by major users and 51 percent by minor users.

These proportions were applied to the 1980 base consumption totals by user category, to determine the water consumption by major and minor user and by type of use. The water demand projections (see Water Demand Projections report) estimated consumption by industrial and nonindustrial users in each category for 1990, 2000, and 2020. For this analysis, it was assumed that the breakdown between water use by major and minor users would remain constant throughout the planning period.

In the nondomestic case studies and major user survey, each type of water use was carefully examined to determine the characteristics of current and future use and associated conservation potential. Several key factors for estimating the water conservation potential associated with process and cooling water use were ascertained.

- The proportion of water use which is ineligible for water conservation was determined, i.e., that water use which cannot feasibly be eliminated because of the nature of finished products, cooling systems, or production processes. About half of the process use by major and minor manufacturers, and major nonmanufacturers and an even larger portion of use by minor nonmanufacturers is characterized this way.

- The proportion of water use which is already being used with the optimum efficiency was determined, i.e., that water use which has already had conservation measures applied to it. The amount varies by type and size of user group; major users have generally accomplished more conservation than minor users.

- The proportion of water use representing the potential for additional savings was determined. Within this:

  - a portion is associated with efforts that have completed part of the full conservation potential and assumes that cost justified measures have been implemented and remaining measures are either infeasible or marginally feasible;

- a portion is associated with efforts that are marginally feasible; and,

- a portion is associated with efforts that are cost justified. This includes cooling water conservation potential assumed in baseline projections (4 percent in 1990, 8 percent in 2000, and 10 percent in 2020) and the remainder which is eligible for conservation.

In general, conservation measures related to cooling water use are anticipated to be 50 percent effective for major users and only 30 percent effective for minor users. This assumes that even with implementation of conservation measures, cooling water use will not be entirely eliminated because installation and operation of air-cooled condenser units and chemically cooled systems are more costly and often less feasible than water cooled systems. The effectiveness of other potential conservation efforts is linked to the anticipated response of each user group to the three demand management programs.

A large amount of nondomestic water use is concentrated in the consumption patterns of a relatively few individual major nondomestic users. By design, therefore, these programs are targeted toward major users. The effectiveness of the programs on process and cooling water use is greater for major users than for minor users. The following assumptions were made on the effectiveness and response rate of nondomestic demand management programs on water use practices in process, cooling, and sanitary applications.

- The potential for future conservation in process water use was limited to that which could be accomplished by installing flow regulating and control instrumentation, checking for leaks, and improving overall maintenance standards and employee awareness of water conservation. These efforts are generally low in cost and are implemented in combination with routine maintenance tasks. Other measures related to conservation of process water were excluded from these programs because their cost is often prohibitively high (on the basis of water savings alone) and because individual process technologies and physical plant characteristics make it difficult to achieve broad-reaching results for a wide variety of users. The low level of effort program assumes that 5 percent of the total conservation potential of major and minor users will be achieved by general education mailings. The moderate and high level of effort programs are

targeted, each with equal emphasis, on the major users and are expected to achieve 20 percent of potential conservation through aggressive education and enforcement. The moderate and high effort programs will be half as effective on minor users, who will not be as aggressively pursued. Achievements in process conservation are expected to remain constant throughout the planning period.

- The potential for future conservation in cooling water use includes that associated with both implementation of low cost, maintenance-related measures (e.g., leak detection, flow regulating devices, etc.) and installation of some higher cost systems (e.g., closed cycle, reuse systems, etc.). The low effort program assumes that 50 percent of those measures which are cost justified by private investment criteria will be implemented by major users and 25 percent by minor users as a result of general education. The moderate effort program assumes that as a result of targeted education and enforcement, all cost justified measures will be implemented by major users, and half of all cost justified measures will be implemented by minor users. The moderate effort program also assumes that some measures that are marginally feasible (those closest to cost justified) will be implemented (50 percent by major users and 25 percent by minor users), encouraged through public subsidy or other incentives. The high effort program assumes that all cost justified measures will be implemented by major and minor users. This program also assumes that the implementation of marginal measures by major users will be subsidized to the extent necessary to make them cost justified. Under the high effort program, only 25 percent of the marginal measures of minor users will be subsidized, equivalent with the moderate program, because the high program is targeted principally at major users.

- The programs assumed that installed flushometer valves reduce toilet flow by 10 percent, faucet restrictors reduce flow by 30 percent, and low-flow showerheads reduce flow by 25 percent. The low effort program assumed 10 percent of eligible toilets were retrofitted in 1990, 5 percent in 2000, and 0 percent in 2020; 15 percent of eligible sinks and 4 percent of showerheads were retrofitted throughout the planning period. The moderate program assumed 25 percent of eligible toilets were retrofitted in 1990, 20 percent in 2000, and 15 percent in 2020; 50 percent of eligible sinks and 8

percent of showers were retrofitted through 2020. The high effort program assumed 50 percent of eligible toilets were retrofitted in 1990, 40 percent in 2000, and 25 percent in 2020; 90 percent of eligible sinks and 10 percent of showerheads were retrofitted through 2020.

By applying the response rate and water saving factor to that portion of water use which is "eligible" for conservation, a water savings or the volume of water conserved under the low, moderate and high programs in 1990, 2000, and 2020 was estimated.

As intended in the design of the nondomestic demand management programs, the largest reduction occurs in cooling water use by major manufacturing users under the high program, accounting for nearly 60 percent of reduction by all nondomestic users in 2020.

The water saving estimates and costs for the nondomestic program are summarized below.

LEVEL OF EFFORT		COST	WATER SAVINGS 1990	2000	2020
•	Low				
	MDC	$2/MG	2.6	1.7	1.6
	nonMDC	Insignificant	1.8	0.8	0.3
•	Moderate				
	MDC	$33/MG	5.5	6.8	8.0
	nonMDC	$35/MG	1.1	1.4	1.7
•	High				
	MDC	$135/MG	7.1	8.8	9.4
	nonMDC	$121/MG	1.4	1.8	2.1

WATER PRICING

To assess the effectiveness of pricing as a demand management alternative, several analyses were undertaken, including:

- the direct and indirect costs of using water;
- water price levels and rate structures;
- the elasticity of demand for water in response to changes in price;
- the experiences with water pricing policy reported in the literature; and,
- case studies of some Massachusetts communities which have increased their water rates.

As a result of these analyses, the following conclusions were made:

- Communities in the study area are assumed to move to full-cost recovery for water and sewer services under the baseline forecast as permitted under Proposition 2½. This results in price increases of 100 to 200 percent in most communities [to about $1.00 per hundred cubic feet (ccf) or $1,337 per million gallons (MG)]. Based on similar recent experience these price increases will result in some acceleration in the use of water-efficient devices but relatively insignificant changes in water use practices. These changes are incorporated in the baseline.

- Increases in overall water price, at the levels possible in Massachusetts communities, are not likely to have a significant long-term influence on water use. It is highly unlikely that communities will be able to raise their prices above full cost-recovery due to Proposition 2½ and long-term precedents. But if they did, the level which would induce substantial reductions in water use cannot be determined based on existing experience; and data suggest it would be beyond yet another 50 percent increase in water price.

- Changes in water price structures are possible under Proposition 2½ and could effectively raise prices to some groups of consumers by 400 to 500 percent, particularly if decreasing block rate structures, which exist in a few towns, were to be replaced by increasing block rate structures, such that large users paid more per unit of water than small users. Such changes will induce accelerated adoption of more water-efficient practices or technologies in some cases of large nondomestic users and may make some investments feasible that otherwise would not be, but experience suggests that this effect would be quite limited over the long term, since moderate water price differentials which could feasibly be implemented will rarely make the difference in an investment decision. Such changes are also estimated to be extremely difficult to implement given the general desire in most communities to support the local nonresidential tax base and jobs with favored treatment, if they were to do anything different from equity.

Water Price Necessary to Induce Reduced Water Use

The influence of water price on water demand has been discussed theoretically in the literature and has been examined in actual situations in both the literature and in the Massachusetts case study communities for this study. To identify the water price level at which water demand would be influenced, several factors must be considered:

- Theoretically-derived price elasticities of the demand for water reported in the literature differ substantially from each other and from those associated with recently reported experiences.

- Experiences reported in the literature indicated that it is usually difficult to distinguish between water use reductions associated with a price change and reductions associated with other factors (e.g., watering bans, device installation programs, rising energy prices, etc.).

- The few reports of experiences that claim to distinguish between the effects of changed water prices and other factors indicate that there is a relatively low elasticity of demand for water in response to modest increases in water price, in the range of near 0 to 20 percent.

- The effect of changes in water price over the long term is unclear: experiences reported in the literature and observed in Massachusetts are limited to, at most, a three year response period but more often to only one or two years.

- In Massachusetts communities which have raised the effective cost of water (based on water and sewer charges) to enable full cost recovery, as permitted under Proposition 2½, the cost of using water has increased 140 to 170 percent (e.g., up 140 percent for some Melrose households and up nearly 170 percent for large users in Newton), yet water demand by selected domestic and nondomestic sample groups has only declined by 1 to 5 percent in relation to control communities.

Without other reported or observed experiences where price changes of greater magnitude have had a greater influence on water demand, there is insufficient evidence to determine the specific price level and structure which can be expected to induce a significant reduction in water demand over the long term. In fact, available evidence suggests that water pricing does not have, in and of itself, a significant long-term influence on water consumption trends at the comparatively low price levels

in effect in Massachusetts and New England. There is some evidence to indicate that water pricing may reinforce aggressive and targeted water conservation education programs; however, there is insufficient evidence in Massachusetts or elsewhere to quantify this relationship.

Examination of Current Price Levels and Rate Structures and Ability of Communities to Alter Them

Prior to 1980, the retail water price level in most MDC communities was in the range of $0.30 to $0.60 per ccf or $401 to $802 per million gallons (MG). In response to the rising costs of operating municipal water supply systems and the passage of Proposition 2½, municipalities have been raising their water prices to levels ranging from $0.50 to $1.00 per ccf or $668 to $133 per MG. At the high end of this range, water rates are near or at the maximum limit of full cost recovery as defined by Massachusetts General Law. Within the MDC, 10 communities have recently instituted rates approaching this limit. The remaining 34 MDC communities could still raise their rates to this limit by implementing increases of 20 to 100 percent.

As sewer charges are instituted, the effective cost of using water will increase further. In 1982, 17 MDC communities were levying charges for local sewer service, and 27 MDC communities were not levying charges for local sewer service. Therefore, if sewer charges are added, the remaining 27 communities that still have the ability to raise their rates, could raise the effective water rate by about 200 percent.

Case studies of communities in eastern Massachusetts which have increased their water prices by up to 170 percent since 1980 indicate that the associated response in water demand was minor to negligible. In Melrose, following a price increase of 80 to 140 percent (flat rate to increasing block rate), two years of water consumption data (town-wide and a sample of domestic users) illustrated a decline in demand of 1 to 5 percent from pre-price change levels and levels in similar control communities which did not institute price changes. Other communities, such as Newton and Brookline, also instituted similarly large water price increases; and, although data were available for a more limited response period (six to nine months), preliminary results show a minor to negligible effect on demand.

On the basis of local experience observed in the case studies, an effective 200 percent rate increase would result in a decrease in demand of less than 5 percent

before 1990 (in relation to what would occur without a price increase), and virtually no change by 2020 because the plumbing code would require water-efficient fixtures by that date. This decrease would occur as a result of the users accelerating the retrofit or replacement, if feasible, of sanitary fixtures with more efficient fixtures as required eventually by the new plumbing code; the reduction would not signify a substantial change in water use habits. The water demand projections (see Water Demand Projections report) assume that communities move to full cost-recovery over the next ten years and that plumbing fixture replacement will be slightly accelerated due to the increased water price.

Based on this analysis, water prices would have to be increased to levels above what is currently allowed under state law to achieve a greater influence in water demand. The level of water price increase required to induce a significant decline in demand beyond that forecast in the baseline is not possible to determine; however, a change in Massachusetts General Law and/or a change in generally accepted utility pricing practice would be required to make such price increases possible. The barriers to such a change include:

- The general practice of public water utilities of charging water rates not exceeding that required for full cost recovery precedes Proposition 2½.

- In the Commonwealth, as throughout the nation, the public is fiscally conservative and unlikely to support price increases in excess of actual costs.

If water utilities could set rates substantially above full cost recovery, the impact on water use would be minimal unless water prices could be doubled again. In such an extreme case, most of the potential demand reduction would take place in nondomestic use, since the Massachusetts plumbing code already requires all sanitary plumbing fixtures sold in the state to be water efficient.

Estimates of Water Savings

The pricing programs evaluated were designed to encourage municipalities to increase their water rates to the limit allowed under current (low and moderate effort programs) or amended (high effort program) provisions of Massachusetts General Law. Specifically:

- Some municipalities are currently charging rates at or near those limits (full cost recovery, under Massachusetts General Law) and could not raise their

rates significantly; while others have water rates well below the limit. One possible objective of a pricing program would be to accelerate the rate at which communities currently below full cost-recovery implement water price increases.

- Some communities are currently utilizing peak pricing, increasing block and other rate structures in efforts to manage demand within their service areas; others charge flat or declining block rates. Another possible objective of a pricing program could be to encourage further utilization of increasing block, peak use and other rate structures.

The programs described below are designed to achieve these objectives in varying degrees.

- Low Level of Effort Program: This program will accelerate the pace at which municipalities increase their water rates to full cost recovery. This would be achieved by a general education program designed to make municipal operators aware of the advantages of water pricing policies. The direct cost of this program is estimated to be $25,050 in labor for administrative personnel and $900 in educational materials. These estimates do not include the potentially substantial costs to be paid by consumers for water, since it is assumed that other taxes would be reduced proportionately (there would be a loss of Federal income tax deductions for individuals however). The reduction in water use which would occur as a result of these price increases is estimated to occur only within the next ten years with no net effect remaining by 1990.

	MDC Communities Reduced Water Use (MGD)	nonMDC Communities Reduced Water Use (MGD)
1990	0	0
2000	0	0
2020	0	0

- Moderate Level of Effort Program: This program will accelerate the pace at which municipalities increase their water rates to full cost recovery and will aggressively encourage the broader use of increasing block and peak demand rate structures, as appropriate. This will be achieved by an aggressive and comprehensive education program targeted at municipal water departments. The direct cost of

this program is estimated to be $38,500 in labor for administrative personnel, plus $1,200 for educational materials for each of two years. As above, these estimates do not include the potentially substantial additional costs to be paid by consumers for water because it is assumed that other taxes would be reduced proportionately. The estimated reduction in water use occurring as a result of price increases will be:

	MDC Communities Reduced Water Use (MGD)	nonMDC Communities Reduced Water Use (MGD)
1990	0	0
2000	0.3	0.1
2020	2.7	0.7

- High Level of Effort Program: This program assumes that changes in Massachusetts General Law would allow communities to charge more than the full cost recovery limit and is designed to encourage communities to raise water rates to 50 percent above that limit. This will be achieved by an aggressive and comprehensive education program targeted at municipal water operators. The cost of this program will be $38,500 in labor for administrative personnel for the first year and $14,500 in labor for the years thereafter. Educational materials are estimated to cost $1,200 per year for the duration of the planning period. The reduction in water use occurring as a result of these price increases is estimated to be:

	MDC Communities Reduced Water Use (MGD)	nonMDC Communities Reduced Water Use (MGD)
1990	7.2	1.7
2000	7.1	1.7
2020	7.1	1.8

Summary of Impacts

It is anticipated that water pricing as a demand management technique would result in the following impacts:

- user-related: increased annual water bills at constant rates of consumption; increased annual sewer bills (as relevant) at constant rates of

discharge; reduced property taxes to offset these increases in user charges, and increased personal income taxes due to the loss of deductions resulting from a shift to user charges;

- municipal water, utility-related: increased annual water revenue at constant rates of user consumption; increased annual sewer revenue (as relevant) at constant rates of sewer discharge; and,

- MDC-related: increased administrative responsibilities and expenses associated with orchestrating the pricing program with each of the 44 MDC communities and the 36 potential future user communities. This effort will involve providing technical assistance to these communities in their water pricing and rate structure policies. In addition, under the high effort program, the MDC and participating communities would have to examine the legal implications of raising rates above full cost-recovery. A change in the current statutes and/or local laws may be required.

TAX INCENTIVE PROGRAMS TO ENCOURAGE WATER CONSERVATION

The use of tax incentives to encourage water conservation was studied to determine potential effectiveness of such programs in the MDC area. This analysis indicates that:

- there has been relatively little experience with tax incentive programs to encourage water conservation;

- the most widely reported experience occurred in California, where statewide residential and agricultural water conservation tax incentive programs have been employed. This experience shows an extremely low participation rate by eligible users, a relatively high cost (in terms of lost tax revenue) compared to other water conservation programs, and an unknown impact on water use;

- industrial and other nondomestic users are not particularly attracted to special tax incentive programs, because of the perception that extensive efforts are needed to comply with eligibility requirements for relatively low financial benefits. This perception is based, at least in part, on prior experience with special pollution abatement and energy conservation tax programs; and,

- the general perception of many public agencies that other water conservation programs are more effective than a tax incentive program in reducing water use

at a lower cost, including: leak detection and repair programs, plumbing code revisions, and distribution of water saving device kits combined with education programs.

PUBLIC BUILDING DEVICE RETROFIT

Water conservation in public buildings was examined to determine what conservation programs have been implemented and what potential exists. This analysis supplements analyses conducted on nondomestic conservation potential (see Nondomestic Conservation section). It was confined to state and federal office buildings for which consistent and complete water use and other relevant data could be obtained. Publicly-owned or operated institutional facilities were evaluated in the Nondomestic Conservation analyses and were excluded from this analysis.

Both the achievements and potential for conservation in both state and federal buildings are limited for several reasons.

- Many of the major public buildings are owned by private companies with the Commonwealth and federal governments occupying them as tenants. Consequently, water billing for these facilities is not centralized and facilities (particularly plumbing fixtures) cannot be controlled by the tenants. Five buildings owned and occupied by the Commonwealth, Massport's facilities at Logan Airport and four federally-owned and occupied buildings were the foci of this examination.

- In the past, water conservation efforts have often been combined with energy conservation efforts. As a result, faucet restricting devices have been the most widely employed conservation measure. Few of the buildings under study have been retrofitted with sanitary devices (only Massport buildings and the J.F. Kennedy Building, at the time of this study). More retrofitting and other conservation efforts are planned but have been postponed due to budgetary constraints.

- Most of the sanitary water use for toilet flushing in these public buildings is by flushometer toilets. With the exception of the J.F. Kennedy Building, building superintendents reported that the benefit of adjusting flushometers is limited (no energy savings) and that few, if any, have been adjusted.

- Some reduction in cooling and heating system use has occurred as a result of improved standards in routine maintenance practices.

- The conservation achievements associated with those buildings that have installed faucet restrictors or improved maintenance standards are uncertain because master water meters have been replaced or adjusted during the period of interest. Consequently, total water consumption data are not consistent from year to year, making it difficult to measure the impact of these conservation efforts.

Conservation anticipated in public buildings is likely to occur principally as a result of the improved water using efficiency associated with the natural replacement of plumbing fixtures required by the Massachusetts plumbing code and continued improvements in maintenance practices. The changes in water use as a result of compliance with the code are included as part of the water demand forecasts for nondomestic users (see Water Demand Projections report). Additional modest conservation could be achieved if the MDC were to fund it or provide other encouragement through information transfer. Education may have a positive impact on water use in publicly owned and occupied buildings, particularly if directed at building superintendents who are in the best position to achieve results and have generally indicated a willingness to improve water efficiency. Building superintendents are generally aware of some of the potential benefits of conservation associated with device retrofit; however, they have been constrained by shrinking public budgets limiting expenditures on efforts that are not an absolute necessity.

Under a demand management program, the MDC could provide information emphasizing the benefits of improved maintenance practices. This would cost approximately $100 or less (the cost of educational materials) and would reduce consumption in these buildings by 3.7 MGY in 1990, 3.8 MGY in 2000, and 3.4 MGY in 2020. These estimates assume constant baseline consumption equivalent to 1980 consumption, and the demand management program is comparable to the moderate nondomestic program, excluding shower use.

The nondomestic demand management program covers institutional buildings, such as hospitals and schools, and those which are publicly-occupied but privately-owned. Consequently, nondomestic water saving estimates associated with that demand management program include these buildings. Although the experiences illustrated by the case studies conducted for this

analysis can provide an example for other public buildings in the Commonwealth, it would be misleading to estimate potential reductions for all public buildings solely on the basis of these case studies and other available information. Such estimates would be based, in part, upon the number of government employees and institutional, office and other non-institutional employment and associated reported water use (institutional, non-institutional, etc.).

If the MDC were to pursue a program to encourage more efficient water use and general maintenance practices within public buildings, principally through technical assistance and information transfer to building engineers/superintendents, the MDC would work closely with the staff of local water departments. Local staff are likely to have established contacts with key personnel at target public buildings and can monitor the impacts of these programs. To the extent that additional reductions in water use occur as a result of improved efficiency of sanitary and cooling equipment, reductions in water revenues will occur as a direct impact on the local water department and an indirect impact on the MDC.

NONEMERGENCY EDUCATION

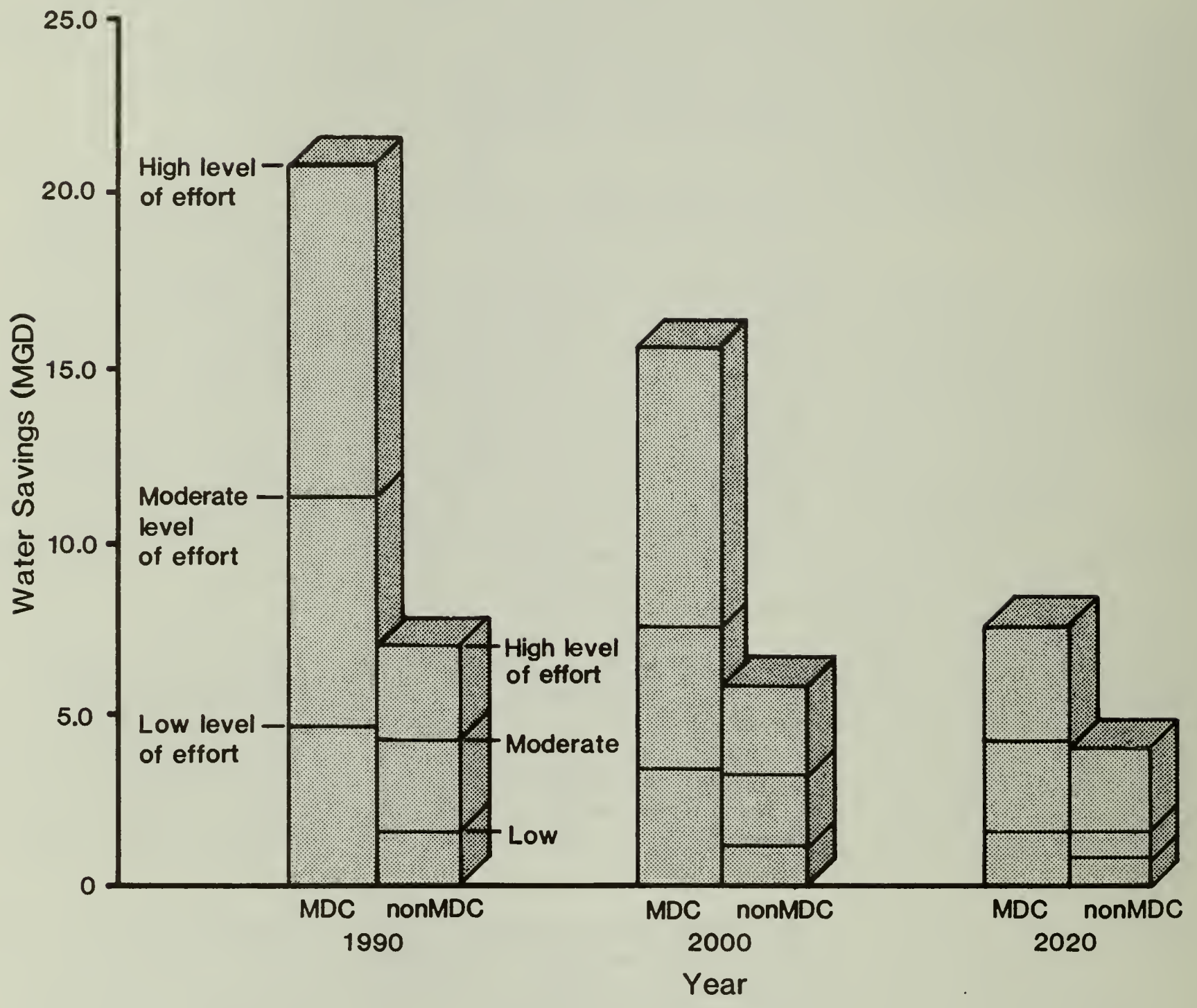
Public education programs have been used in most water conservation projects to encourage adoption of water conserving habits, or to support other conservation programs. For public education to be successful in the MDC area, programs must be comprehensive, frequently repeated and modified to accommodate the various characteristics of the different communities within the MDC.

The three levels of effort public education programs are summarized in Figure 4, "Summary of Nonemergency Education Programs" for the 44 current MDC communities (MDC) and the 36 potential future MDC user communities (nonMDC).

Plumbing Code Affects Long-Term Water Savings

The Massachusetts plumbing code will affect the expected water savings from the public education program in a manner similar to its affect on savings for the device retrofit program. Specifically, as homeowners replace standard plumbing fixtures with water efficient fixtures, required by the code, water savings from device retrofit that were encouraged by the education program will decline. The combined effect of the plumbing code and public education program will be a decline in average water use, but the portion of the decline contributed by

Figure 4.
Summary of Nonemergency Education Programs



High Level of Effort:

Cost MDC $ 914/MG
nonMDC 485/MG

Comprehensive advertising, customer technical assistance, and printed materials on conservation techniques.

Moderate Level of Effort:

Cost MDC $ 502/MG
nonMDC 332/MG

Advertising and printed materials on conservation techniques.

Low Level of Effort:

Cost MDC $ 91/MG
nonMDC 183/MG

Public service announcements and printed materials on conservation techniques.

the education program will be smaller as the planning period progresses. If the plumbing code were not in effect, then water savings from the nonemergency education program would remain relatively constant over the planning period.

Impacts

The major negative impact of this program would be the difficulties the MDC might experience in the implementation of the high and moderate levels of effort. These programs are very labor intensive and would require the addition of many new staff positions, or the subsidization of local community personnel to complete the work. Further, the MDC would be managing a program unlike any of its other water supply programs because of the heavy reliance on voluntary user cooperation and professional advertising. To maintain water savings from these programs, they would have to repeated every year, without interruption.

Another significant impact of a long-term nonemergency education program is related to how the consumer could respond during short-term water crises. Because this program would focus on user habits which are easy to adopt, then such easy measures would no longer be available for use during a drought. To achieve additional savings during an extreme water emergency, extraordinary measures would be required.

Wastewater flows could be significantly reduced under the high and moderate levels of effort. Indoor water conservation activities should reduce wastewater flow in proportion to water saved. However, the total quantity of water saved is not expected to significantly reduce waste- water flows to the MDC sewer system. For those users not part of the MDC sewer system or who are still using on-lot disposal systems, then some improvement in operation of those systems might be expected.

Water revenues to each community and the MDC would drop if significant water savings were achieved. For MDC communities, these decreases might be balanced by the subsequent decrease in their payments to the MDC. For nonMDC communities, the range of savings, by community, shows that those which are primarily residential may suffer a drop in revenues that might have to be compensated for by an increase in the water rate. For those with a mix of residential and nonresidential users, the drop in water revenues could be insignificant.

For the MDC, water revenues might be reduced but probably not enough to affect the overall budget.

The significant positive impacts of a public education program are related to the positive image the MDC can gain through such a program and a general increase of the public's awareness of water supply issues. Frequently, the public receives poor information that leads them to wrong conclusions about how a utility operates and why conservation programs are implemented. The education program can improve awareness of the MDC that will eventually make other programs easier to implement as well.

Derivation of Water Saving Estimates

The water savings estimates were calculated using two factors: the water saving factor, or how much water could be saved in a household after the actions suggested by the public education program were implemented; and the response factor, or how many households would respond to the programs. To develop the water saving factor and the response factor, the following analyses were completed:

- determine water uses that could be targeted by the education program by reviewing water use patterns analyzed for the Water Demand Projections report;

- determine how much water can be saved by households once the water conservation actions were adopted, the water saving factor, by reviewing water use patterns analyzed for the Water Demand Projections report and results of other education programs reported in the literature;

- design programs which the MDC would implement to encourage adoption of water conservation actions; and,

- estimate the percentage of households that would respond to the MDC public education program, response factor, by reviewing similar programs implemented in Massachusetts and the country, and by reviewing water use patterns analyzed for the Water Demand Projections report.

The water saving factor would then be multiplied by the response rate for each community to estimate total water savings within each community. Community water savings were added to derive water savings for the existing MDC water users, and potential future user communities.

Derivation of Water Saving Factor

From review of public education programs implemented by other water utilities, it was determined that the best

use of these programs was to encourage users to adopt easy-to-accomplish actions. Programs that requested users to complete difficult, or time consuming actions had less success than those that focused on easier to accomplish tasks. To specify the types of actions that a water conservation public education program would focus on in the MDC area, the domestic water use patterns (see Water Demand Projections report) were reviewed. Domestic use patterns that indicated potential to be easily reduced were identified and included the following:

- water use for bathing, approximately 22 gallons per capita per day (gpcd), approximately a 6 minute shower;
- water used in sinks for washing and food preparation, approximately 5.5 gpcd for bathroom use;
- outdoor use, ranging from 9.5 gphd to 35 gphd;
- water use for toilet flushing, approximately 27 gpcd; and,
- other household uses, such as laundry, dishwashing, and cleaning.

To encourage reduction of these uses, the public education program would focus on two techniques: changing water use habits to those that are more water efficient; and installing water saving devices. The derivation of water saving factors for water saving devices is summarized in the section on Domestic Device Retrofit.

The actual water savings that could be expected from changes in user habits would vary significantly from household to household; however, an average water saving factor was derived based on the water consumption patterns estimated in the Water Demand Projections report. The estimated water saving factors are summarized below.

- Limiting shower time (or minimize bath water level) would reduce water used for bathing by approximately 18 percent, or from 22 gpcd to approximately to 18 gpcd (average shower time of 6 minutes at approximately 4 gallons per minute reduced to 5 minutes at approximately 3.5 gallons per minute, flow rate assumed low flow showerhead is eventually installed in most households).

- Limiting running water in sink would reduce sink water use by approximately 50 percent, or from 5.5 gpcd to approximately 2.75 gpcd.

- Outdoor use could be reduced by 25 percent to reflect maximum efficiency in landscape irrigation. This factor is the only one that can be verified from results of other conservation programs that have dealt solely with outdoor water use. Those programs include Tuscon, Arizona's Beat-the-Peak program, the Madison, Wisconsin program and watering bans in New England all of which have resulted in substantial savings in outdoor use, from 10 percent to 50 percent of summer use, for example. These programs indicate that outdoor water use could easily be reduced by 25 percent, even in the East Coast, where average outdoor water use is much less than in midwest and southwest.

- Toilet flushing only for intended purposes would reduce toilet water use by approximately 10 percent, or from 27 gpcd to approximately 24.75 gpcd.

- Reduction of 5 percent for the rest of household water use would reflect adoption of other habit changes, such as using dishwasher only when full, not running tap water to get desired temperature, and changing level of washing machine to reflect load size.

Water saving factors from user habit changes would remain relatively constant over the planning period. Such savings could be achieved in the future even as baseline domestic water use factors decline by 2020 (see Water Demand Projections report) because the decline is due to installation of water conserving appliances, in compliance with the plumbing code and would not influence water savings attributable to user habit changes.

Derivation of Response Rates

To maximize adoption of water conservation behavior during nonemergency times in the MDC area, research shows that the education program should be quite different from past efforts. A comprehensive electronic media advertising program would be necessary. This must be supported by companion printed materials and personal contacts with residents. The advertising program would encourage residents to adopt conservation behavior, and the support programs would show residents exactly what can be done. A market survey would also be required to determine the public's awareness of water issues, its knowledge of water conservation, and its attitudes

towards water in general. The specific education materials could then be designed to fill in gaps of knowledge and change attitudes, if necessary.

The response rates summarized below for three different levels of effort are based on research of public education campaigns conducted by nonprofit organizations other than water utilities (such as energy and communications utilities, public interest groups, and charities). They indicate a range of response to reflect individual community characteristics. Higher response rates are expected in primarily single-family areas as opposed to primarily multi-family communities. Response rates also vary based on which element of the public education program water users might adopt. Response rates are lower for adoption of user habit changes; response rates are higher for installation of water saving devices.

Program	Response Rate
High Level of Effort	15 to 40 percent
Moderate Level of Effort	5 to 25 percent
Low Level of Effort	0 to 10 percent

Despite the wide use of advertising, implementation of behavior suggested by public education campaigns or by advertising campaigns of private companies was difficult to quantify because most public agencies rarely quantify the effectiveness of their programs, and private companies were unwilling to publish specific market research data. However, three institutions did attempt to quantify the effectiveness of their public education campaigns in New England. The U.S. Department of Energy (DOE), Corporation for a Cleaner Commonwealth, and New England Telephone all encouraged residents to change some basic behavior pattern: energy consumption by implementing several energy conservation techniques, littering by adoption of different trash disposal techniques, and use of directory assistance by using the phone book more often. These programs showed that with comprehensive electronic media advertising accompanied by companion printed material, an average of 20 to 40 percent response could be expected. These studies, as well as other public education programs by local energy utilities and nonprofit organizations, indicate that less comprehensive efforts will yield substantially less response. If residents only read printed materials, or only see or hear electronic advertisements, response rates drop considerably to approximately 3 to 5 percent.

Derivation of Cost Estimates

All costs for design and reproduction of public education materials were based on the background research, interviews with private advertising and public relations companies, interviews with printing and reproduction centers, and costs from previous and ongoing MDC public education programs.

All labor costs for publicly supported personnel are based on 1982 MDC and local community salaries for similar positions, plus 32.5 percent of base salary for benefits. All other program costs (consultant fees, materials, office rental, transportation, reproduction, and postage) are based on 1982 costs for similar services and products.

The net present value (NPV) of the total program costs were calculated for each level of effort. The net present value figure represents the 1982 value of the cost of the program over the 40-year planning period. It incorporates a 5.5 percent factor for inflation, an 8 percent discount rate, and an 8 percent interest on any capital expenditure that would be paid for by bond.

Program Design

All the education programs will encourage users to adopt water saving use habits and to install water saving devices. Water savings will not be attributable to one particular element, the combination of implementing all the program elements would result in a decrease in water demand.

Each level of effort program includes both a regional media campaign utilizing television, radio, and newspapers to convey the overall message of water conservation, and a support campaign utilizing pamphlets, school programs, and other printed materials which instruct users on specific conservation techniques.

The most expensive element of each program would be the regional media campaign due to advertising costs and the need to update the advertisements each year. For the high and moderate levels of effort, another expensive element would be the technical support personnel who provide direct assistance to domestic users.

POTENTIAL FOR USE OF NON-POTABLE WATER BY SELECTED USERS

Introduction

This report includes the assessment of the technical and economic feasibility of the use of non-potable water by large industrial and institutional water users and one urban fire system within the MDC's current and potential future service areas.

Four types of non-potable water were studied: non-potable groundwater, river water, seawater, and wastewater treatment plant effluent. After initial review of potential users, it was determined that there was little potential for additional seawater use. Therefore, that source was dropped from further consideration. Also, it was difficult to find potential users for wastewater treatment plant effluent. Virtually all of the municipal sewage within the Metropolitan Water District (MWD) service area is treated at either the Nut Island or Deer Island Wastewater Treatment Plants. It was not feasible to consider effluent from either of these two plants as a source of water to any of the major water users because the treatment plants are far from any of the potential users.

Methodology

The study is divided into four major elements: identification of current and potential users of non-potable water; interviews with selected current and potential users; eight specific case studies, and a projection of the potential for use of non-potable water in the current MDC service communities and potential future user communities.

The current and potential non-potable users were identified from survey information of large users conducted under Phase IA and Phase II of this study. Users were considered if they consume more than 10 million gallons per year (MGY), at least 30 percent of which is used for cooling purposes. Fifteen current large users were identified which use a total of 50 MGD of non-potable water. These current users were surveyed to obtain background information. Sixty potential users of non-potable water were identified, and the 40 largest of these users were surveyed to determine the nature of their water use and their potential for using non-potable water. Those with the most potential for conversion to non-potable water use were selected as case studies.

Potential Water Savings

In the case studies, conceptual designs for conversion to the use of non-potable water were developed and the costs of conversion were estimated for the selected users. Although only a few specific cases were studied, those facilities studied are estimated to account for over half of the total potential for use of non-potable water within the current MDC service area. The results of the case studies were then used to make projections of the potential for use of non-potable water in both the current MDC service communities and the potential future user communities.

The total potential for use of non-potable water is estimated to be as follows:

Potential Users Grouping	Estimated Total Potential
Group of 40 large, users within MDC (interviewed)	1500-2200 MGY (4-6 MGD)
Group of 20 additional, large, users within the MDC	100 - 300 MGY (0.3-1.0 MGD)
TOTAL MDC	(4-7 MGD)
Users in potential future user communities	limited

In the current MDC service area, the possibility exists for four to seven MGD of municipally supplied water to be replaced by the increased use of non-potable water by the 60 potential users identified in the study. About 70 percent of this potential is associated with 10 of the users within the currently supplied MDC communities. Six of these are case study facilities which represent 3.5 MGD of the potential.

The greatest potential for use of non-potable water is for use as non-contact cooling water. For non-contact cooling, cooling water is isolated from the product, such as water used to cool machinery used in processing. For direct contact cooling, cooling water is either sprayed directly onto the product or the product is immersed in a water bath.

For potential future user communities, very little opportunity for non-potable use (less than 0.5 MGD)

appears to exist. These possible individual users appear to be smaller water users than those in the current MDC service area. It is estimated that the conversion of these possible users to non-potable water might not be cost-effective (with or without public support) because they are smaller water users for which the unit costs of non-potable water would be expected to be higher.

Cost-Effectiveness of Non-Potable Water Use

The economic feasibility of conversion to non-potable water use was evaluated from the standpoint of both public and private investment. Under public investment, it was assumed that the MDC would develop the non-potable source of water, operate and maintain the pumping and treatment facilities, and sell the non-potable water to the users of the water. For private investment, it was assumed that the potential users of non-potable water would develop, operate and maintain all facilities associated with the non-potable water supplies. The cost-effectiveness of the private investment program took into consideration the savings in municipal water cost and the tax advantages of developing and operating the non-potable water supply facilities.

The private investment analysis indicated that if the price of municipal water increases to $1337/MG ($1.00/ccf) as projected (Chapter Seven: Water Pricing), it will be cost-effective for five of the seven manufacturing companies studied, to convert to the use of non-potable water. Conversions of these companies would effectively save 2.6 MGD of municipally supplied water.

The public (MDC) investment analysis indicated that it is currently cost-effective to convert only four of the seven manufacturing companies studied, and one option of the urban fire system, to the use of non-potable water. A savings of 2.8 MGD of municipally supplied water could be realized. If the price of municipal water increases to $1337/MG as estimated, conversion of all remaining manufacturing companies studied becomes cost-effective, for a total savings of 3.8 MGD (two case studies were the same facility, but with different sources of non-potable water).

Therefore, if the MDC decides to institute a program of financing water supply and treatment facilities for non-potable water use instead of waiting for private industries to make the conversions, about 3 MGD of municipal water could be currently saved and 4 MGD could be potentially saved. The range in unit costs of non-potable water for these case studies is from $70 to $1040/MG.

For large users not studied as part of the case studies, it appears that the potential for use of non-potable water will become cost-effective with time. Therefore, the total estimated potential of 4 to 7 MGD should become cost-effective as the price of water increases. However, the unit cost of non-potable water for the potential users not studied will probably fall in the high end of the $70 to $1040/MG range.

Impacts

In general, the development of non-potable water sources by either the private user or the MDC could result in some of the following impacts:

- a lowering of water levels and reduction in flow in surface water sources from which non-potable water is withdrawn and not returned;

- an increase in water temperature (if the non-potable water is returned to a surface water source after use for cooling purposes);

- a lowering of groundwater levels and possible impact on the yields of nearby wells (where the non-potable water is withdrawn from a groundwater source);

- an increase in flow to municipal wastewater treatment plants as a result of discharge streams from water treatment plants for the non-potable water (e.g. filter backwashes, reverse osmosis rejection stream); and,

- public health problems resulting from illegal or unconcious connections to a non-potable water line, for potable water use.

However, if the potential users of non-potable water are carefully selected and the facilities are properly designed, most of the impacts could be minimized. For several of the cases studied, increased wastewater flow would result, but in only one case would any of the other impacts result. In this case, a noticeable reduction in river flow during certain months of the year could result.

Implementation Problems

The MDC could face several problems in implementing a program to develop and operate facilities for supplying non-potable water to some of its users. These are:

- the need for more trained personnel to operate the pumping, treatment and maintenance facilities;
- the problems associated with obtaining long-term purchase commitments for non-potable water from potential users;
- the risks of investment based on potential long-term contracts;
- the legal constraints to the implementation of the program;
- the problems associated with meeting and maintaining quality standards and quantity commitments to users of non-potable water; and,
- the possible public opposition resulting from concerns about the potential impacts listed above.

Many of these impacts might not occur if the facilities were built and operated by the users themselves.

Development and operation of the water supply facilities by the MDC would put the MDC in a very vulnerable position financially, unless it can obtain long-term commitments from potential users. The MDC's involvement might require either insurance or legal support to minimize the risk of losing the user of non-potable water after development of a source. Also, it is likely that with time, the user's demand for non-potable water might decline through the installation of more water-efficient equipment. This would result in reduced revenue to the MDC which it would have to counteract by increasing the price of non-potable water to the users.

Finally, the MDC (the supplier of potable water to the communities) might find itself competing with the local water departments if the MDC develops and operates the non-potable water facilities. In doing so, the MDC would be taking water customers away from the local communities and therefore reduce the communities' water revenues.

DROUGHT RESPONSE PLAN

A three stage drought response plan was designed to reduce demand incrementally in response to increasingly severe drought conditions and is designed to minimize the risk of supply failure during these periods. The plan, as summarized in Table 3, "Summary of Drought Response Plan", would cost approximately $47,118,000 (in 1982 dollars) and would provide the MDC with one management tool to lower the risk of system failure during emergency

periods. During months prior to a potential system failure, withdrawals would be reduced to levels that could be tolerated by the water users of the MDC system without causing severe hardship. Severe hardship is considered to include: disruption of the economic activity of the region; personal hardship to homeowners, and high rates of diversion of local water utility personnel to drought response activities.

The drought response plan accounted for the effects of baseline water conservation activities, such as the reduction in domestic per capita water use due to compliance with the Massachusetts plumbing code. The long-term effect of such baseline water conservation activities is to minimize the flexibility of water users to respond to emergency situations.

The drought response plan quantifies the level of emergency action that would be required to reduce the risk of supply failure. It provides the MDC with a tool for determining how severe the drought situation is, and when to implement different levels of emergency actions. This drought plan relies completely on reducing withdrawals by reducing water demand. The water savings expected from this plan do not affect long-term water demand because the plan is implemented only when there is a drought. According to the safe yield analysis (see Safe Yield - Existing System report for full safe yield analysis), the drought plan could increase existing system safe yield by an average of 3.0 MGD. Alternative drought response plans could include supply augmentation, such as new source development or use of Quabbin Reservoir water below the minimum to ensure adequate water quality.

The combined storage of Quabbin and Wachusetts reservoirs is used as an indicator for drought severity. The initiation of the drought response stages are related to the combined storage. As storage drops, drought severity increases, and increasingly stringent emergency actions are implemented. The actions required for the drought response plan are summarized below.

Drought Watch. Before programs are implemented which would ask users to reduce water use, the MDC would conduct an in-house drought plan review; update it where necessary; and contact local officials and the media to inform them of the possibility of a water shortage. These actions are initiated when the Quabbin and Wachusetts reservoirs' combined storage is approximately 50 percent. If reservoir storage continues to drop, the MDC would prepare Stage One programs to ensure that the materials and personnel required for Stage One would be

ready. The preparation activities would include design, printing, and distribution to communities of public education materials; coordination with state and local officials; and issuance of the voluntary use restrictions that will be used in Stage One.

The safe yield model results indicate that this program would be needed about four times during a 50-year period.

Stage One. This set of programs would be initiated when the combined storage of Quabbin and Wachusett Reservoirs drops to 45.5 percent of full capacity. The programs are voluntary and would not achieve significant water savings. However, they would provide water users with the information they would need in the eventuality of worse drought conditions, and they would help reinforce the public's perception of a potential crisis.

The main focus of this program would be the public education program, including the full implementation of the public education materials prepared during the Drought Watch. The MDC would be involved in the following activities: paying for advertising on TV, radio, and newspaper to encourage users to conserve water and to publicize the voluntary use restrictions; coordinating distribution of the pamphlets/brochures by communities; and contacting all major users to assist them with development of a water conservation plan specific to their uses.

If reservoir storage continues to drop, preparation for Stage Two would begin. More public education materials would be produced, and mandatory use restrictions would be sent to local officials to ensure they would be prepared to implement and enforce them in their communities.

The major cost for Stage One would be the costs to advertise on television, radio, and the newspapers. The results of the safe yield model indicated that this program would be required about four times, for a total of 30 months. The costs for Stage One are $3,644,800 (1982 dollars), of which $135,600 would be for local communities' expenditures to distribute printed education materials.

Stage Two. When the combined reservoir storage of Quabbin and Wachusett Reservoirs drops to 40.5 percent, the Stage Two programs are implemented. At this point, the water supply would be significantly low, and more stringent emergency actions would be required. A mandatory program for domestic users would be included, which would reinforce the public's perception of the

seriousness of the drought. A comprehensive voluntary program for both domestic and nondomestic users would also be implemented.

As in Stage One, the major focus of Stage Two emergency actions would be public education. The advertising program would be continued, and the printed materials produced in Stage One would be reproduced and redistributed to remind users of specific conservation actions they can adopt. The education program would also focus attention on the mandatory use restrictions that require reduction of outdoor water uses.

To complement the domestic program and to reassure domestic users that they are not the only water users making a sacrifice, a voluntary nondomestic program would be initiated. An average 10 percent use reduction would be requested, with the MDC providing direct technical assistance to users through water audits.

The MDC would also become more involved with other utilities and agencies in the midst of a drought response plan to maintain consistency among programs if possible, and to lend support and assistance.

During this Stage, the participation by the local community would be greatly increased because enforcement of restrictions would best be accomplished by local enforcement personnel. Local water department staff would continue to assist the MDC with distribution of public information materials.

If reservoir storage continues to drop, the MDC would design and prepare new education materials on the Stage Three rationing program for domestic users, and on the mandatory percent reduction program for nondomestic users. It would initiate planning for comprehensive leak detection and repair programs and coordinate with local officials on the requirements of the Stage Three programs to ensure they would be prepared to implement and enforce them.

The major costs for this stage for the MDC are for the purchase of television, radio and newspaper advertising space. For local communities the major costs would be approximately $33 million for enforcement personnel. This program would be in effect about 17 months in 50 years, and would cost approximately $35,753,200 (1982 dollars).

Stage Three. When combined storage of Quabbin and Wachusett Reservoirs drops to 38.0 percent of full capacity, Stage Three would be initiated. At this point, Quabbin would be just above minimum pool, or the point at which water quality and ecology would decline.

To minimize reservoir withdrawals, a domestic rationing program would be implemented that would allow each user 30 gallons of water per day. This type of program is considered equitable during a crisis because it allows each user the same amount of water and allows him/her to use it any way he/she chooses. The nondomestic program would require a 25 percent use reduction, based on the previous years' annual average use, or some other specified value based on the MDC water audit.

Both of these programs would be supported by a comprehensive education program that would provide users with information on the program, penalties for violation, tips on how to comply, and how to seek exceptions.

The local communities' efforts which would be applied to enforcing the program, would probably require additional meter readers and possibly enforcement personnel.

The MDC would continue to coordinate its programs with the rest of the state, to support local communities' activities, to review exceptions to the rationing programs, and to brief the media. The MDC, as well as the local communities, would also be intensifying their leak detection and repair programs.

The major MDC costs for this stage would be for advertising. The major costs for local communities would be for enforcement. The total costs would be approximately $7,463,700 (1982 dollars). This stage might be required for about 4 months in 50 years. Another major cost would be loss of water revenues to both the MDC and local water departments due to the significant drop in water use. Because the fixed costs to operate water utilities are a very high percentage of total costs, a significant drop in revenues could cause serious cash flow problems.

It is unlikely, but possible, that the drought could get worse, at which point the MDC would be forced to implement programs that would cause severe hardship. Possible programs that the MDC might have to consider include the following: adjustment of residential 30 gallon per person per day allotment to 20 gallons per person per day; adjustment of nondomestic 25 percent use reduction to 50 percent; shutting down of nonessential businesses; increased efforts at leak detection and

repair; and using nonpotable water wherever possible. The impacts of such measures would be severe: the economic livelihood of the region would be seriously affected, public health and safety might be threatened; and hardship may be suffered by individual users.

Alternatives to such severe water use restrictions would be supply augmentation options. Additional water could be supplied by allowing the reservoirs to drop below minimum pool levels, or by taking water from another large source. The impacts of these types of actions would be to threaten water quality and the ecology of the reservoirs.

Severe water use restriction or supply augmentation programs have not been included in the design of this drought plan.

ANALYSIS OF COMBINING DEMAND MANAGEMENT PROGRAMS

EFFECTS OF COMBINING PROGRAMS

When individual demand management programs are implemented simultaneously the water savings and costs cannot simply be added together. Three major components of each program must be reviewed before final water savings and costs of the program combinations can be estimated. The analyses of these components, and how they interact when combined with other programs, are important because the expected water savings and costs of program combinations could change significantly as a direct result of the combination. The potential effects that program combinations might have on these three components are summarized below and are based on experience with similar programs, as reported in the literature in the Demand Management Interim Technical Report (see Chapters Two through Twelve).

Water use that will be affected by the program

Affected water use is the category of water use that will be reduced by the program. For example, the affected water use of a domestic device retrofit program is indoor domestic use. If the affected water use is the same among the programs to be combined, then some adjustment to the water savings must be made because the same water cannot be saved twice. For example, if a public education program that encouraged installation of devices were implemented at the same time as a device distribution program, then water savings from both programs could not be achieved because both programs rely on saving water from users' installing devices. If the affected water uses were different, then the water savings among the programs could be added without adjustment.

The incentive used to encourage participation in the program

Incentives usually used in water conservation programs include an incentive to encourage users to save water to save money (economic), an incentive to encourage users to save water to benefit themselves or the community (voluntary), and an incentive which requires users to save water to comply with the law (mandatory). Depending on how these incentives are mixed, the effectiveness of the program combinations in encouraging user participation could be enhanced, or remain unchanged. If the incentives among programs to be implemented simultaneously are different, then the effectiveness of the participation in some programs may be enhanced, while

participation in other programs would probably be reduced. This effect would depend on the relative influence the programs have within the service area. For example, if a public education program (voluntary) were to be implemented simultaneously with a water pricing program (economic) in the MDC service area, the response to the public education program might be increased. A pricing program, as a single economic incentive to save water, would be expected to result in a relatively low or negligible response (see section on Water Pricing). However, in combination with a voluntary program, it might emphasize the need to adopt water conserving actions suggested by the public education program.

The method that will be used to implement the program

Usually water utilities implement water conservation programs in three ways: by using advertising and general promotion techniques; by providing direct technical assistance to the users; or by providing direct financial assistance. When programs are implemented simultaneously, then the costs to implement them would either be reduced or remain unchanged depending on which implementation techniques are being used. If the incentives were to be the same, then costs could be reduced by combining two efforts into one program; if the implementation techniques were different, then the costs to implement the program combination would likely remain the same as if implemented separately.

The three major components were identified for each long-term demand management program (see Chapters Two through Twelve of the Demand Management Interim Technical Report for details), and are summarized in Table 11, "Factor Analysis for Long-Term Demand Management Programs".

PROGRAM COMBINATIONS, WATER SAVINGS, AND COST ESTIMATES

Four example program combinations were developed according to different strategies that have been used by other utilities for long-term conservation programs. The specific adjustments to costs and water savings are representative of what could be expected to happen based on best professional judgement and experience from other multiple water conservation programs reviewed as part of the literature searches for the individual program assessments (see Chapters Two through Twelve of the Demand Management Interim Technical Report). The effects of each of these plans on the drought response plan are

Table 11. Factor Analysis for Long-Term Demand Management Programs

PROGRAM	FACTORS		
	Affected Water Use	Incentive to Encourage Participation	Technique to Implement Program
Reduction of unaccounted-for water	Unaccounted-for water	Economic	Direct technical and/or financial assistance
Pressure reduction	All Uses	Economic	Direct technical and/or financial assistance
Domestic leak recovery	Domestic Leakage	Voluntary	Direct technical assistance and/or advertising
Domestic device retrofit	Indoor domestic domestic	Voluntary	Direct technical assistance and/or advertising
Nondomestic conservation	Process, cooling, and sanitary nondomestic	Voluntary	Direct technical and/or financial assistance
Water pricing	All domestic and nondomestic uses	Economic	Direct technical assistance
Public building device retrofit	Sanitary nondomestic	Voluntary	Direct technical assistance
Tax incentives	Domestic and nondomestic	Economic	Advertising
Nonemergency education	Indoor and outdoor domestic	Voluntary	Direct technical assistance and advertising
Potential for use of nonpotable water	Process and cooling - selected users only	Economic	Direct financial assistance

also estimated. The water savings and costs that would be achieved from these program combinations are summarized in Figure 5, "Combinations of Four Demand Management Plans for MDC and nonMDC Communities". (Note: if demand management programs for the MDC and nonMDC communities were implemented simultaneously, the costs and water savings would be added.) These plans illustrate the effects of combining programs and are summarized below.

Plan No. 1, No User Participation (Strategy No. 1, Public Agency Action Programs)

Plan Description This plan would include programs that would rely entirely on the MDC and water utilities' actions to achieve water savings by reducing water distribution system losses. It would eliminate the need to include domestic and nondomestic water users in the program.

The specific demand management programs that would be part of this plan include reduction of unaccounted-for water through improved system management practices (improved meter maintenance, leak detection and repair, and reduction of unmetered public water use) and pressure reduction. These programs were selected for this plan for two reasons. First, unlike any other demand management program, no user participation is required for these programs to be successful. Second, the potential water savings from these programs could increase over the planning period. It should be noted that the meter maintenance program does not actually achieve water savings; it only accounts for more water by improving the accuracy of the meters.

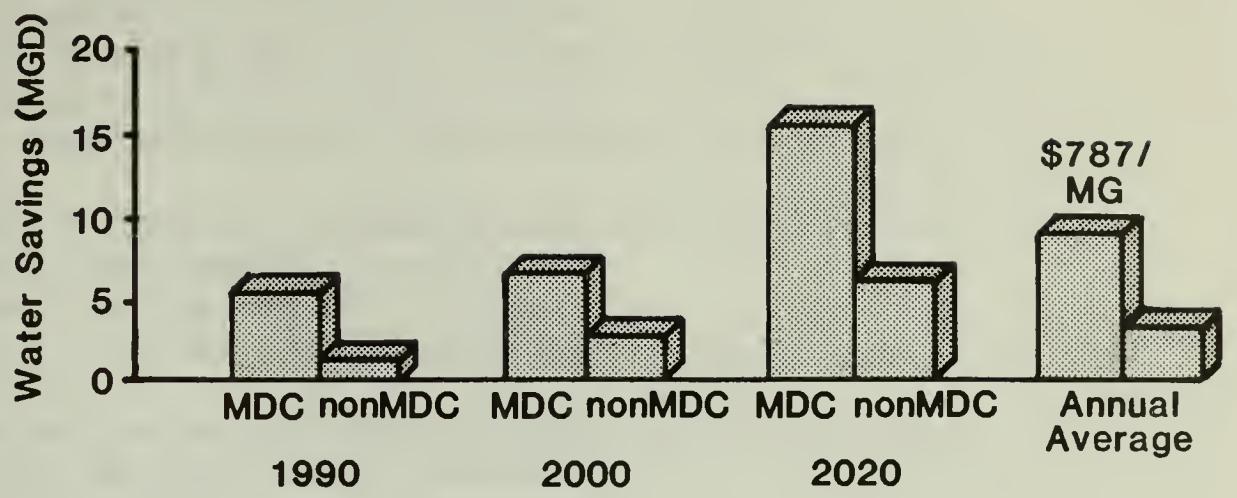
Both of these programs would be implemented directly by the MDC and the local water utilities. They would essentially be more intensive applications of existing, regular system maintenance practices, except that additional staff may be required.

Water Savings and Cost Estimates. The water savings and costs from implementing reduction of unaccounted-for water through improved system management practices and pressure reduction would be affected if these programs were implemented simultaneously. There would be some duplication in water savings because some affected water uses (system leakage) and incentives (economic) are the same. Pressure reduction programs are expected to reduce water losses due to system leakage by approximately 3 percent within the areas affected. The primary source of water savings for reduction in unaccounted-for water

Figure 5.
Four Demand Management Plans for MDC and nonMDC Communities

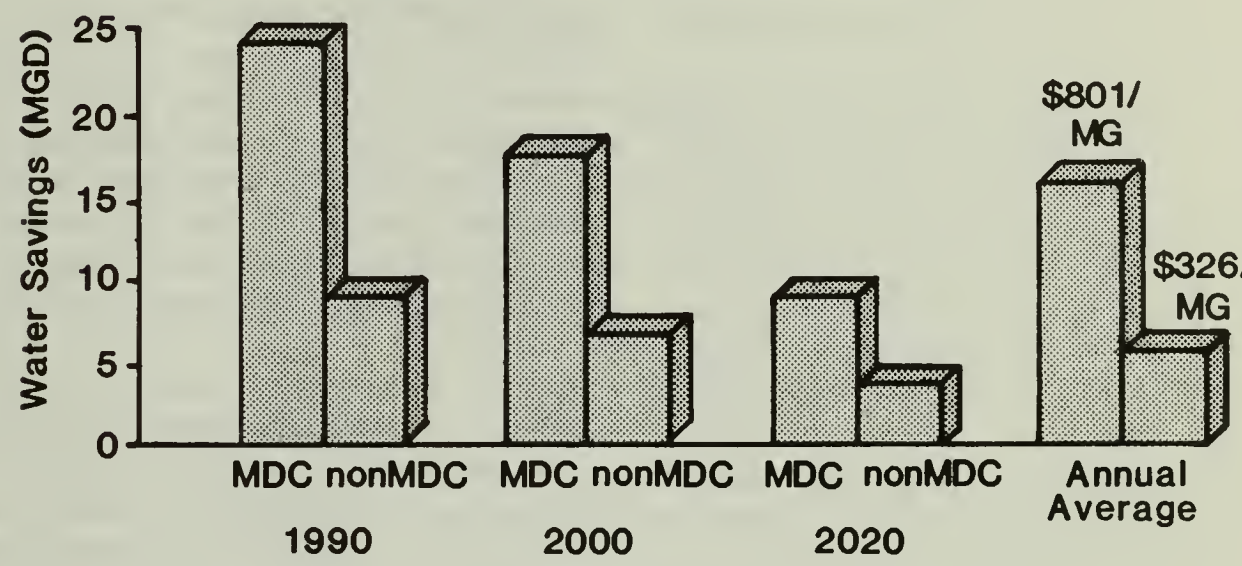
Plan No. 1

No User Participation
- o system leak detection and repair
- o meter maintenance
- o low level of effort pressure reduction



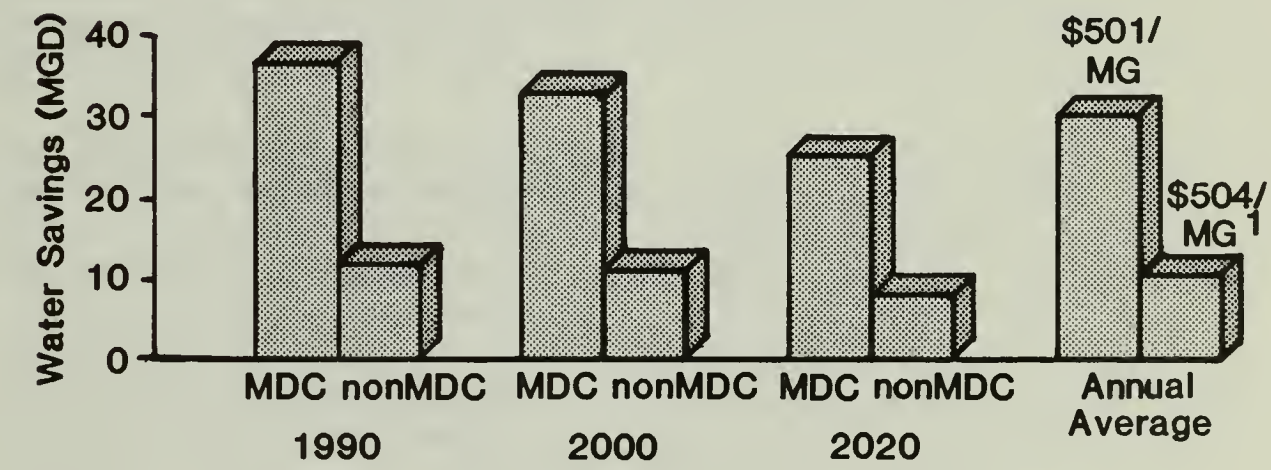
Plan No. 2

Voluntary Participation
- o high level of effort nonemergency education
- o low level of effort domestic leak recovery and domestic device retrofit
- o low level of effort nondomestic conservation
- o low level of effort pricing



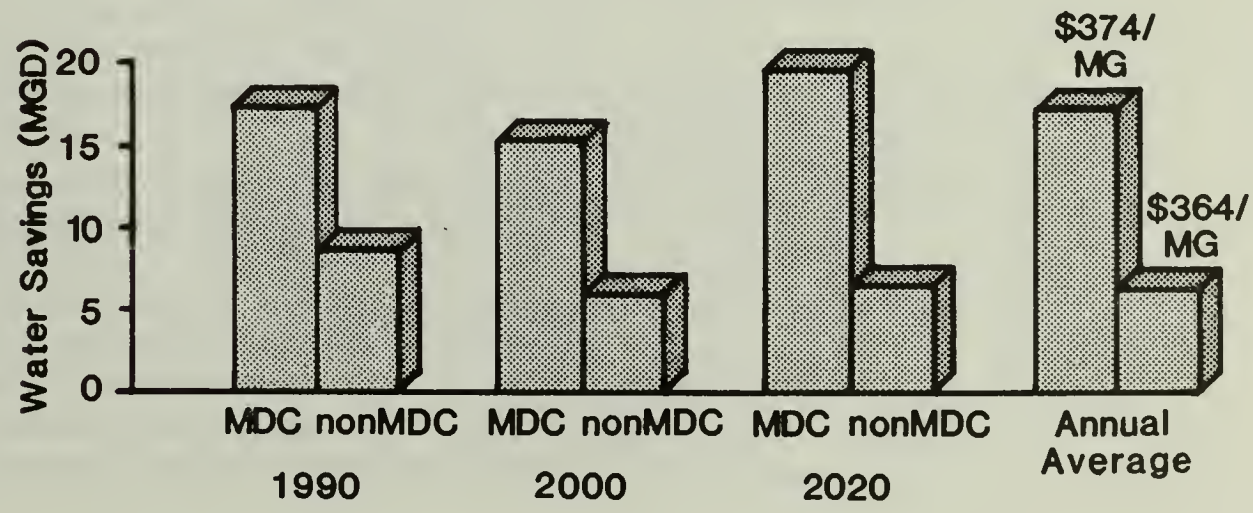
Plan No. 3

Provide Direct Technical Assistance
- o high level of effort domestic leak recovery and domestic device retrofit
- o moderate level of effort nondomestic conservation
- o use of nonpotable water, public facilities



Plan No. 4

Achieve Water Savings from all Use Sectors
- o system leak detection and repair
- o moderate level of effort device retrofit
- o moderate level of effort nonemergency education
- o low level of effort nondomestic conservation
- o low level of effort pricing



[1]Unit costs do not include nonpotable program

would also be from reducing system leakage, so some water savings would be duplicated. Although both programs would involve working with the water mains, any duplication of effort would be insignificant. Therefore, there would be no adjustment to program costs.

As a result of the combination effects, water savings from reduced leakage due to pressure reduction would be reduced by 75 percent and unaccounted-for water savings would remain the same.

This plan would achieve long-term water savings which increase from 5.2 MGD in 1990 to 15.3 MGD in 2020 for MDC communities. For the 36 nonMDC communities, water savings would increase from 1.7 MGD in 1990 to 5.7 MGD by 2020. The unit cost of the plan, based on the total net present value of the plan divided by the total amount of water saved over the planning period would be $787/MG. These costs are somewhat high because no direct water savings benefits can be attributed to the meter maintenance program, which is an expensive program. If meter maintenance were not included, the cost would be $238/MG.

Effect on Drought Response Plan. If this plan were implemented, the expected short-term savings from the drought response plan would not be significantly affected. Because comprehensive leak detection and repair programs would be implemented over the long-term, no additional water savings could be expected from the leak detection component of the drought response plan.

The effect on the drought response plan's water savings and costs would be as follows:

- Stage One - no effect on water savings, no effect on costs;

- Stage Two - no effect on water savings, no effect on costs; and,

- Stage Three - water savings decline by approximately 1 percent in both winter and summer seasons, costs decline by approximately $500,000.

Plan No. 2, Voluntary Participation (Strategy No. 2, Combined Public Agency and Private Actions)

Plan Description. This plan would include programs that would rely entirely on voluntary participation by domestic and nondomestic water users. This plan would require substantial additions to the MDC staff and participation by local community staff to achieve

significant water savings.

This plan includes the following long-term programs:

- high level of effort nonemergency education;
- low level of effort domestic device retrofit program;
- low level of effort domestic leak recovery program;
- low level of effort nondomestic conservation program; and,
- low level of effort water pricing program.

The high level of effort nonemergency education program was the only voluntary domestic program that resulted in significant water savings over the long-term. The moderate and low level of effort nonemergency education programs were not comprehensive enough to achieve significant savings. Independent of any other program, the other voluntary domestic programs (low level of effort domestic device retrofit and domestic leak recovery) are too limited to achieve substantial savings. However, the comprehensive nonemergency education program could incorporate the specific messages of the individual programs relatively easily. Because the high level of effort nonemergency education program would be so comprehensive, it would be the most influential element of this plan.

The low level of effort nondomestic conservation program is the only nondomestic program which does not offer direct financial incentives to private companies. Both the high and moderate levels of effort programs require technical and financial assistance. Although this nondomestic program does not achieve substantial savings, it would provide a balance to the domestic voluntary program, so that domestic users do not feel that they are the only water users participating in the water conservation plan.

The low level of effort water pricing, as an individual program, would not achieve significant savings. It may serve to reinforce the objectives of public education, particularly the device retrofit aspects of the public education campaign. However, at current price levels, water pricing is not likely to affect water use habits and therefore would have virtually no impact on long-term water use habits. In combination with the comprehensive voluntary program, it could provide some additional economic incentive to users to participate in the

voluntary programs, at least during the first 10 years of program implementation. Thereafter, its effects would be negligible. The high level of effort pricing program (water rates 50 percent higher than full cost recovery) was not be included because it is extremely unlikely that it could be implemented within Massachusetts communities, which do not usually approve fees to exceed full cost recovery.

Water Savings and Cost Estimates. The water savings and costs for these programs would be significantly affected if implemented simultaneously. For the domestic water use programs, the affected water uses (indoor use), incentives (voluntary), and implementation techniques (advertising) are similar. However, the water pricing program adds a small economic incentive which would likely enhance the effectiveness of the domestic programs only during the first 10 years of implementation.

Of the domestic programs, the most influential would be the high level of effort nonemergency education program because it is a more aggressive program than either of the domestic leak recovery or device retrofit low level of effort programs. Therefore, with relatively minor extra expenses the nonemergency education program could be easily expanded, to emphasize water conservation techniques for devices and leak recovery. The education program would be encouraging water savings to be achieved by device retrofit, leak recovery, and user habit change. Expected water savings for the device retrofit and leak recovery would become part of expected savings from the education program. Therefore, water savings from the education program would be enhanced by about 5 percent. The water pricing program would enhance the effectiveness of the voluntary incentive only during the first few years of implementation. Savings from the education program would be adjusted upwards by 2 percent, for 1990 only. The costs of the nonemergency education program would be increased by 5 percent, and the costs for the other domestic programs, including pricing, would be deleted.

The effect of the water pricing program would be minor on the nondomestic users program, because the current price of water, even at full cost recovery, is still not high enough to significantly influence nondomestic users.

The adjusted water savings and costs from the domestic and nondomestic programs would be added together to calculate total water savings and costs for the plan.

The voluntary plan would achieve the highest level of savings in MDC communities in 1990, when average daily

savings are expected to be approximately 24.7 MGD. Then, as baseline water conservation activities increase, additional water savings from these long-term programs would decline to approximately 9.4 MGD by 2020. The unit cost of the plan, based on the total net present value of the plan divided by the total amount of water saved over the planning period would be $801/MG.

Effect on Drought Response Plan. This plan would greatly reduce the short-term effectiveness of the first two stages of the drought response plan because the same type of water conservation actions are encouraged in the long-term plan and the short-term plan. In the third stage of the drought plan, water conservation activities are different for drought response than the long-term plan. Therefore, water savings expected from Stages One and Two of the drought response plan would likely be negligible; whereas the water savings for Stage Three would probably not be affected significantly. In summary, the following adjustments would be made to the drought plan:

- Stage One, water savings for both winter and summer seasons would be reduced by 34 percent, cost remains the same;
- Stage Two, water savings would be reduced by 55 percent during both winter and summer seasons, costs would remain the same;
- Stage Three, water savings would not be affected, no change in costs.

Plan No. 3, Provide Direct Technical Assistance (Strategy No. 2, Combined Public Agency and Private Actions, and Strategy No. 3, Potential Use of Nonpotable Sources)

Plan Description. This plan includes programs that would provide domestic and nondomestic users with the information, and sometimes materials, to maximize participation in the programs. This plan would also require substantial additions to the MDC staff and participation by local community staff to implement the programs in a manner that would ensure their success.

The plan would include the following programs:

- high level of effort domestic leak recovery;
- high level of effort domestic device retrofit;
- moderate level of effort nondomestic conservation; and,

- conversion to nonpotable water use for selected users (public financing available).

The domestic programs would include the provision and installation for users, at no charge, of water saving devices and completion of leak repairs for indoor and outdoor uses. For the nondomestic programs, the MDC would provide technical assistance to selected users to encourage them to purchase and install water saving equipment specific to each establishment.

The high level of effort domestic device retrofit program was selected for four reasons. First, it would result in substantial water savings through 2000 with a minimum of the domestic users participation. Once the devices were installed, the users would not have to take further action to conserve water. Second, it would be a visible program that would enhance user participation. Third, it could effectively be combined with the high level of effort domestic leak recovery program because both programs rely on personnel going door to door to assist homeowners. Fourth, water savings from both domestic device retrofit and domestic leak recovery programs would be achieved. The moderate level of effort programs for both domestic device retrofit and domestic leak recovery do provide technical assistance but rely more on voluntary user participation for success. Because this plan was to rely on a minimum of user participation, neither the moderate or low levels of effort programs were included because they do not provide any technical assistance.

To complement the domestic program, the moderate level of effort nondomestic conservation program and conversion to nonpotable water (public assistance available) were included because they provide users with the same general level of assistance as the domestic programs.

Water Savings and Cost Estimates. The programs within this plan affect different water uses, so the water savings would not be affected significantly if implemented simultaneously. However, the techniques to implement the program all require the MDC to provide direct technical and/or financial assistance to users. Therefore, costs of the programs would be reduced if implemented together.

The domestic programs, device retrofit and leak recovery, both include door-to-door visits by trained personnel to install devices or to repair leaks. If both device installation and leak repair were completed in one visit, then the labor costs for device retrofit could be almost eliminated because the leak recovery program requires

more effort. However, during the first 5 years of the program, the installation of devices and repair of leaks may require somewhat more time than originally budgeted. Therefore, the labor costs for leak repair will be adjusted by 5 percent, and the cost of the devices will be added directly to the labor costs. Further, water savings from both programs would be achieved because there would be no duplication of water saved, i.e. the affected water uses within the household would be different.

For the nondomestic programs, some financial incentives would be used to encourage installation of water saving equipment or conversion to nonpotable water. The potential users of nonpotable water are likely to be the same users who would respond to the nondomestic conservation initiatives. Therefore, water savings from the nonpotable water use program would be subtracted from water savings achieved by the nondomestic program. Cost for implementation of either program would not be affected.

The major benefits from this plan would occur in 1990 when savings are the highest at 36.7 MGD. As baseline water conservation activities replace the savings achieved from the demand management programs, savings decline to 25.4 MGD by 2020. The unit cost of the plan, based on the total net present value divided by the total amount of water saved over the planning period would be $501/MG. If the nonpotable program were not included, the unit cost for this plan would be $379/MG, with no change in water savings.

Effect on Drought Response Plan. This long-term plan would affect the nondomestic component of the drought plan because nondomestic users would likely implement many of the same type of water conservation techniques for short-term drought as for the long-term program. Therefore, when substantial water use reductions for these users are required in Stage Three, they would be more difficult to achieve and could cause disruption in the day-to-day operations.

This plan would not affect domestic drought response programs as much because the long-term plan focuses on installing water saving devices, which are not included as part of the short-term plan. In summary, the adjustments to the drought plan are as follows:

- Stage One, no change in water savings or costs;

- Stage Two, a 45 percent reduction in both winter and summer seasons water savings, no change in costs; and

- Stage Three, water savings decline by approximately 1 percent during both summer and winter seasons, with no change in costs.

Plan No. 4, Achieve Water Savings from All Use Sectors (Strategy No. 1, Public Agency Action Programs and Strategy No. 2, Combined Public Agency and Private Actions.)

Plan Description. This plan includes implementation of programs that would affect all water use sectors, domestic, nondomestic, and unaccounted-for. It would require some additional MDC staff to manage it but would rely more on voluntary user participation and in-kind services from the local communities.

The following long-term programs would be included:

- unaccounted-for water reduction through improved system management practices;

- moderate level of effort domestic device retrofit;

- low level of effort nondomestic conservation;

- moderate level of effort nonemergency education; and,

- low level of effort water pricing.

Each program would concentrate on reducing use within each use sector, and the nonemergency education and pricing programs would provide added incentives to users to participate.

The improved system management practices program was selected because of the improved system efficiency achieved within the individual communities which implement the program and to benefit the overall goal of reducing demand. Further, this program would be a visible example to water users that the utility is fully participating in the water conservation plan. Only leak detection and repair was included because the other improved system management practices add substantial costs to the program, without achieving substantial water savings.

The moderate level of effort device retrofit program also provides a visible example that water conservation is a top priority within the MDC because MDC and/or local utility personnel distribute water saving devices directly to residents. Water savings would be significant in 1990 when the program would be most active. Then, as water savings decline due to the installation of water saving plumbing fixtures in conformance with the plumbing code, the activities in this program would be phased out. Therefore, for a relatively moderate expenditure, substantial water savings could be achieved before the full impact of the plumbing code is realized.

The moderate level of effort nonemergency education program would be implemented simultaneously to encourage full participation in the device program and to urge residents to maintain their water saving devices after the device program is phased out. The low level of effort program might be too limited to provide an effective long-term support to the device program, and the high level of effort program is expensive.

The low level of effort nondomestic program would be a complement to the other programs. The water pricing program was selected because it might provide an extra incentive to users to participate in the programs during the first 10 years of plan implementation. As an independent program, it achieves virtually no water savings.

Water Savings and Cost Estimates. The water savings and costs from reduction in unaccounted-for water would remain the same, if implemented with these other programs because this program would concentrate on reducing leaks in the distribution system. Therefore, it would not interact in any way with the domestic or nondomestic programs.

Of the three programs which affect domestic water use, (device retrofit, pricing, and education), the device retrofit program would likely be the most dominant in the MDC region. It would be the most visible program, with personnel distributing devices in each community and it would achieve long-term savings with a minimum of individual user effort. The moderate level of effort education program would effectively enhance the response to the device program by increasing the exposure of the program to the residents. Therefore, water savings could increase by approximately 10 percent because more users would be participating in the program. The education program would also achieve water savings independent of the device program, primarily due to changes in seasonal

use and user habits. The moderate level-of-effort education program would encompass the education components of the device program without a significant increase in cost. The capital cost of the device program would not change.

The water pricing program would affect domestic users only during the first 5 years of program implementation. The water savings for device retrofit would be adjusted by 2 percent for the first five years.

The nondomestic conservation program's water savings would probably not be substantially increased as a result of the pricing program. Therefore, the water savings and cost of this program would remain unchanged.

This plan achieves relatively consistent savings over the planning period. In 1990, the majority of the 17.4 MGD savings would be achieved by the domestic programs. Then, as baseline water conservation activities cause declines in the water savings from domestic programs, the expected savings from the unaccounted-for water program increases. By 2020, the majority of the 19.4 MGD savings would come from reduction of unaccounted-for water. Savings from the nondomestic program remains relatively constant. The unit cost of the plan, based on the total net present value of the plan divided by the total amount of water saved over the planning period would be $374/MG. If a low level of effort nonemergency education plan were used instead of a moderate level, the savings would decrease to 13.5 MGD in 1990 to 18.0 MGD in 2020. Costs would decrease to $224/MG.

Effect on Drought Response Plan. This long-term plan would have the similar effects on the drought plan as Plans No. 1 and No. 2. Water savings and costs for the drought response plan would be adjusted for all stages as summarized:

- Stage One, water savings would be negligible, no change to costs;
- Stage Two, water savings would be reduced by 54 percent in both winter and summer seasons, no change to costs; and,
- Stage Three, water savings would decrease by 1 percent in both winter and summer seasons and costs would decrease by $500,000.

BACKGROUND RESEARCH

The results of the literature searches and case studies of individual demand management programs support the overall conclusion that the effects of implementing individual demand management programs simultaneously must be carefully analyzed to estimate the final water savings and costs. The major conclusions are summarized below.

- A public education program could effectively enhance the participation of most domestic demand management programs.

- Although a significant water rate change may not be able encourage significant water savings individually, it could provide an effective economic incentive to other domestic and nondomestic demand management programs.

- A long-term demand management program could reduce the effectiveness of a short-term emergency response program.

- Generally, water system oriented programs (i.e. reduction of unaccounted-for water) do not affect domestic or nondomestic programs.